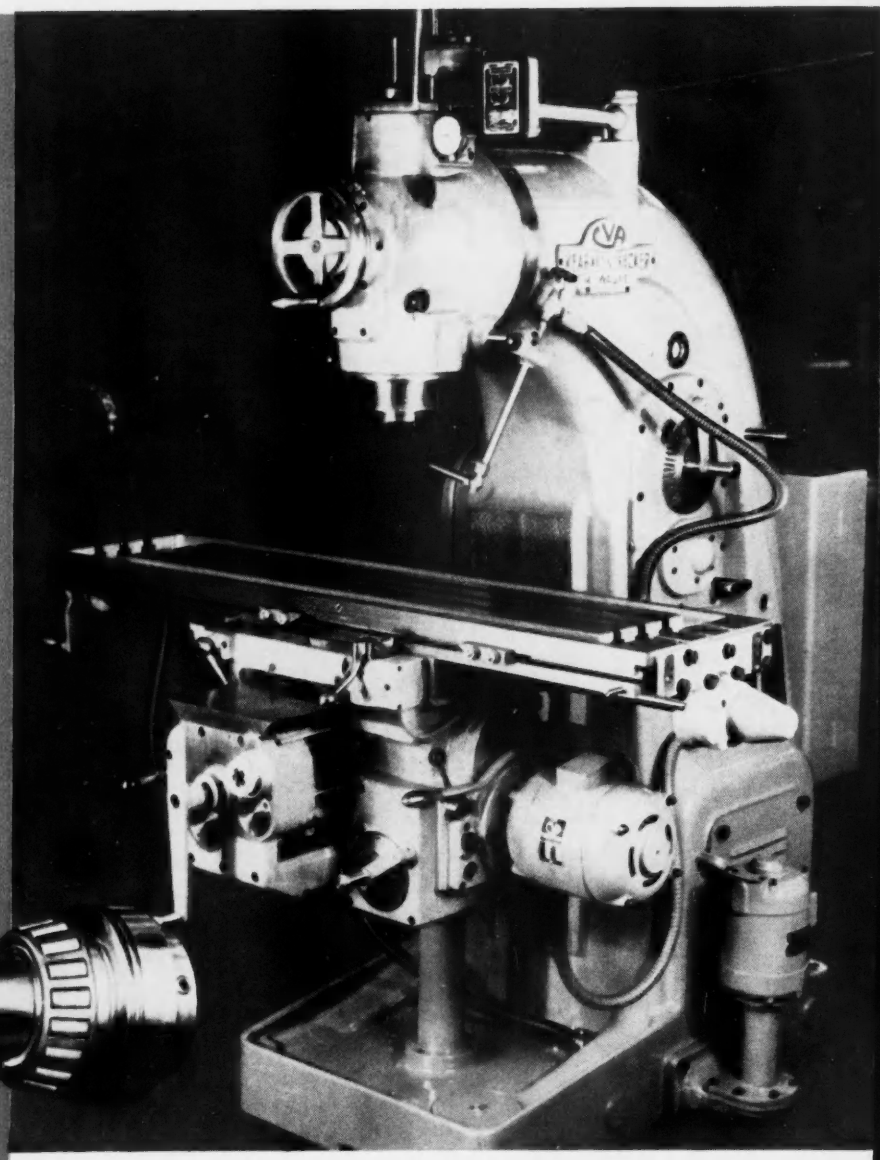
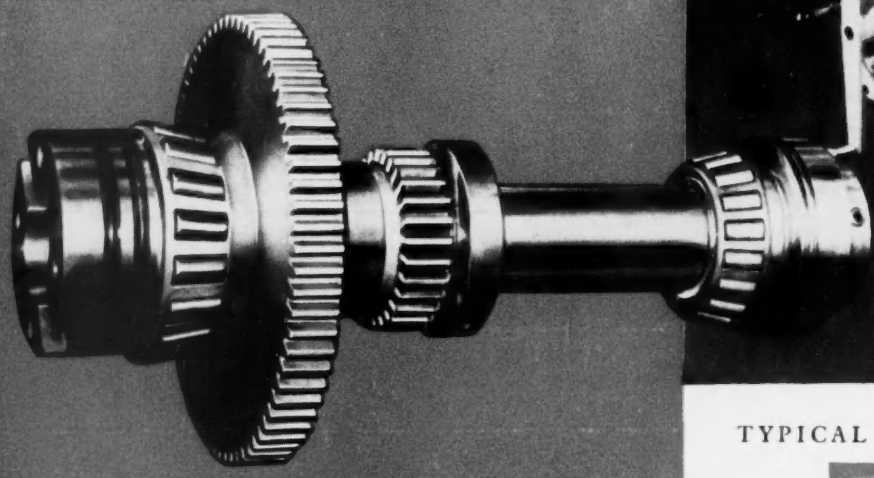
THE ENGINEER

OCTOBER 23, 1959 | 28 ESSEX STREET, STRAND, LONDON, W.C.2 | TWO SHILLINGS

NICKEL ALLOY STEELS ensure reliability in machining

In the current designs of C.V.A. Jigs Moulds & Tools Ltd., Hove, who concentrate on high speed automatic and centre lathes, dieing presses and 'Milwaukee' milling machines, the constructional materials include various nickel alloy steels for the highly stressed components. The 1½ per cent nickel-chromium-molybdenum steel, EN 24, one of the most useful compositions, is used for cams, shafts, spindles and other items which are either made from forged material or bar stock.





The reliability of C.V.A. automatics, now operating in thousands throughout the world, is a reflection of the reliability of nickel alloy steels under sustained stresses.

By utilising the better properties obtainable in more highly alloyed nickel steels, dimensions can be reduced, lighter constructions produced, distortion through heat treatment minimised and reliability and economy achieved.

TYPICAL MECHANICAL PROPERTIES OF

EN24

These steels exemplify its versatility both as regards strength and range of serviceable section sizes.

SIZE	HEAT TREATMENT	YIELD STRESS t.s.i.	MAXIMUM STRESS t.s.i.	ELONGATION per cent	IZOD ft. lb.
0·564" dia.	Oil quenched 830°C. tempered 200°C.	111·4	125·5	14·5	24
1" dia.	Oil quenched 850°C. tempered 510°C.	79·5	83·6	15	28
1½" dia.	Oil quenched 850°C. tempered 560°C.	68·3	73·5	19	55
2½" dia.	Oil quenched 840°C. tempered 650°C.	57·3	64·1	20·5	65
5¾" dia.	Oil quenched 830°C. tempered 650°C.	50·1	58·9	19·5	75

MOND NICKEL

Send for 'The Mechanical Properties of Nickel Alloy Steels' ▶

TGA 21/20A

THE MOND NICKEL COMPANY LIMITED

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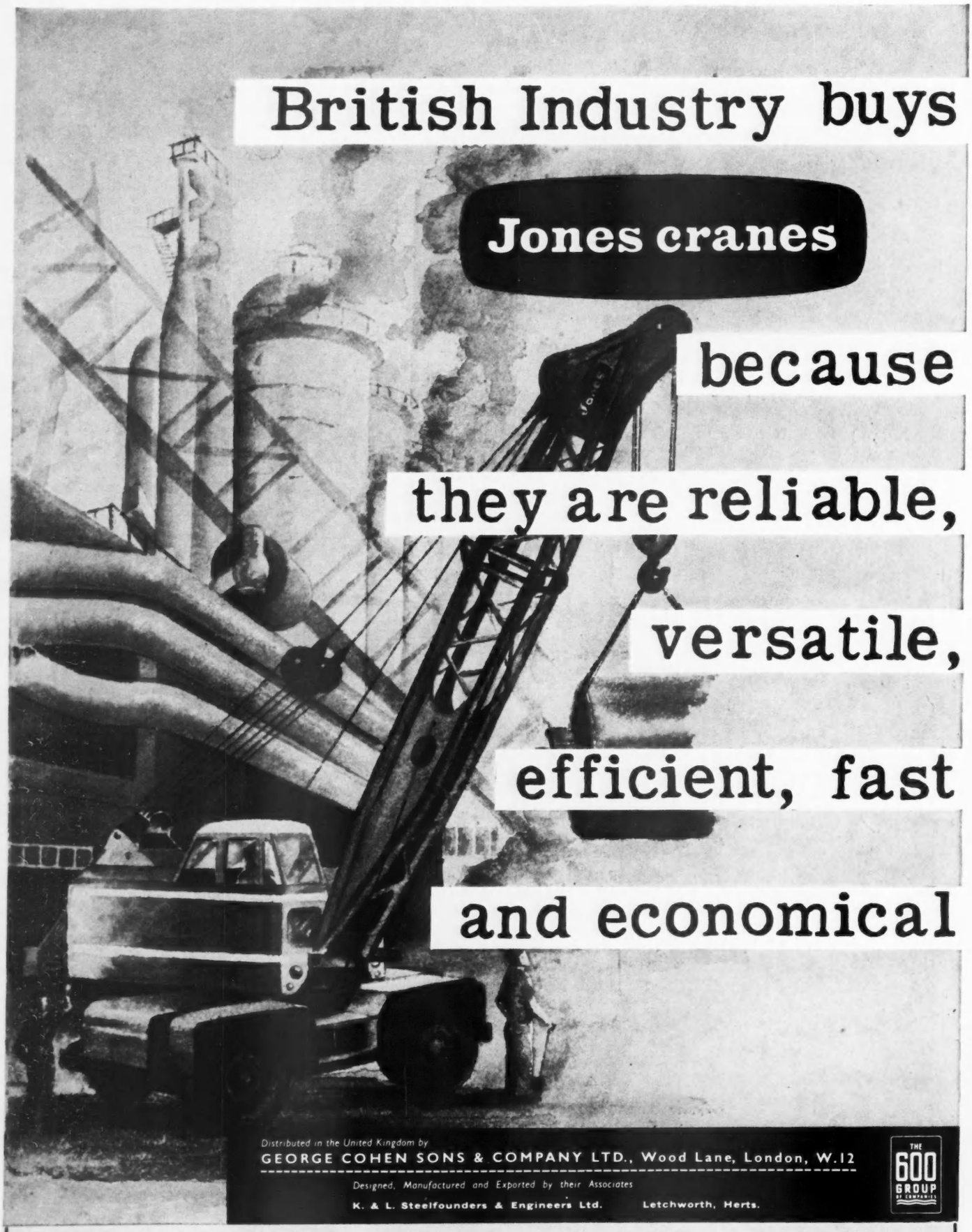
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THE ENGINEER

Established 1856

No. 5413 **OCTOBER 23, 1959** VOL. 208

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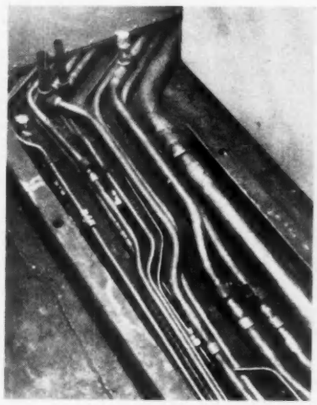

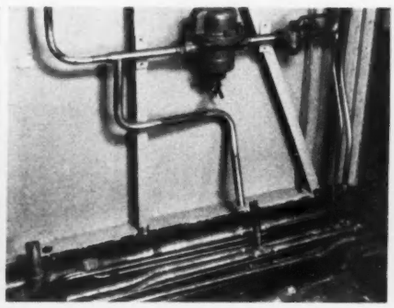

Photographs by courtesy of British Transport Commission

Above: Yorkshire Imperial Copper Tubes and "Yorkshire" Capillary Fittings on air brake and control piping in boiler compartment of British Railways Main-Line Diesel Electric locomotives, Type 2.

Left: Yorkshire Imperial Copper Tubes and "Yorkshire" High Duty and "Instantor" Fittings on air brake and control piping in engine compartment of the above.

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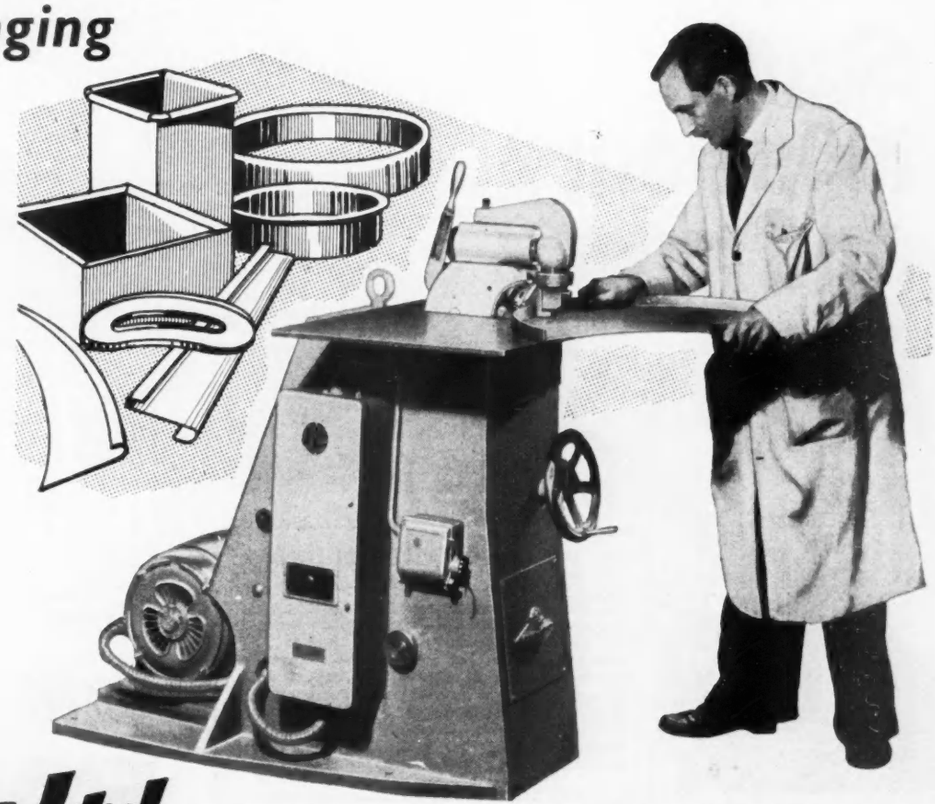

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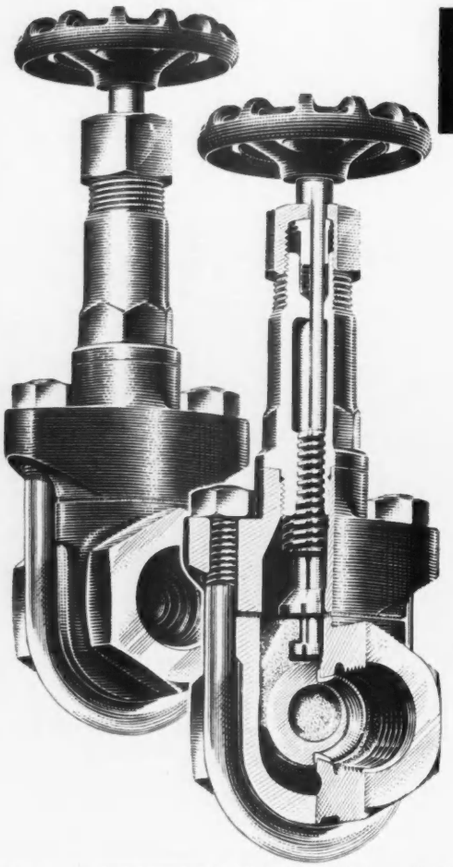

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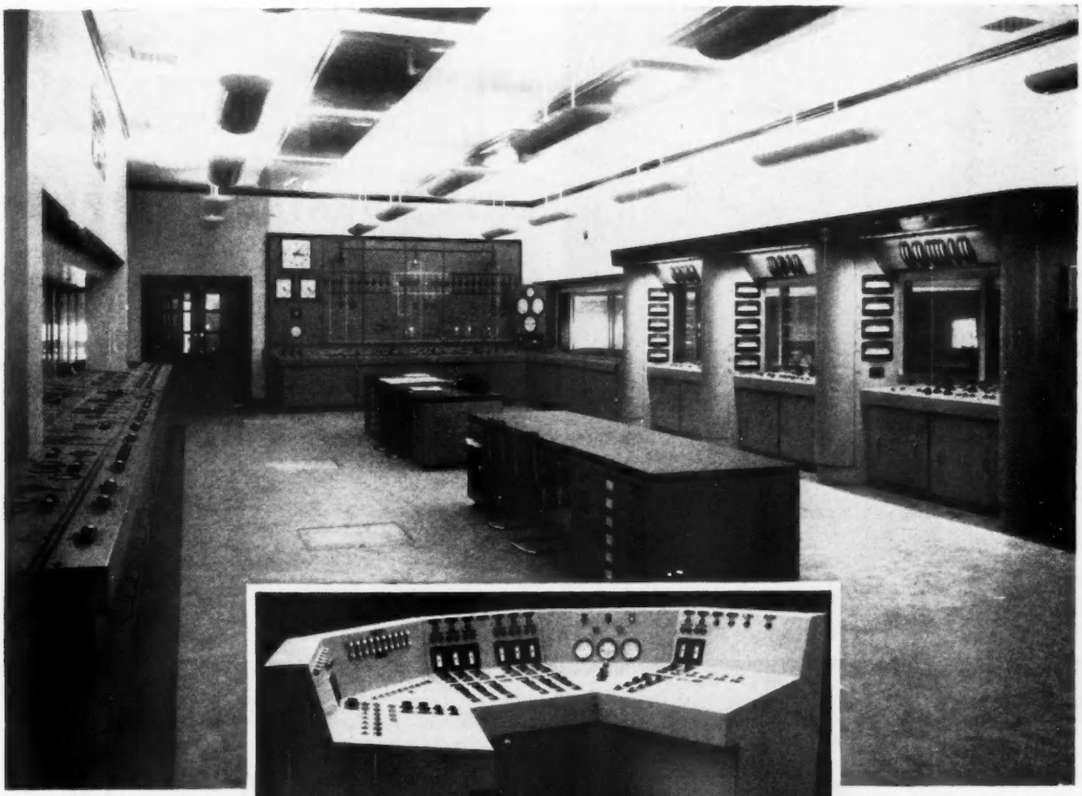
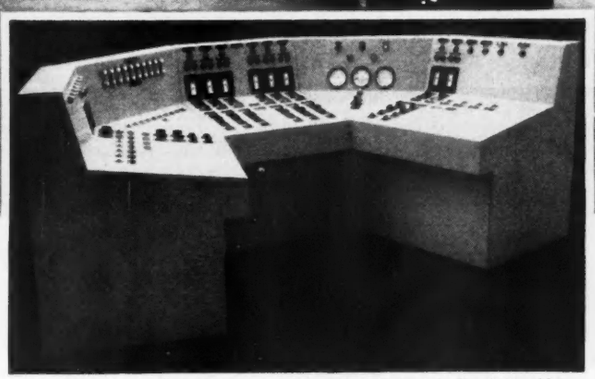


Main Control Room, Ashford Common Pumping Station of the Metropolitan Water Board.



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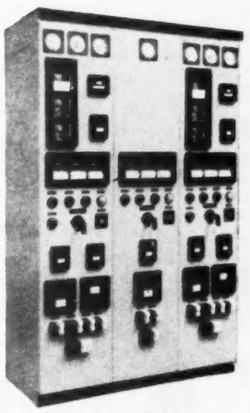

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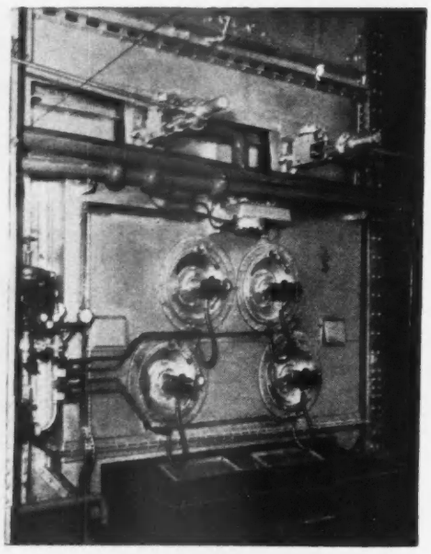

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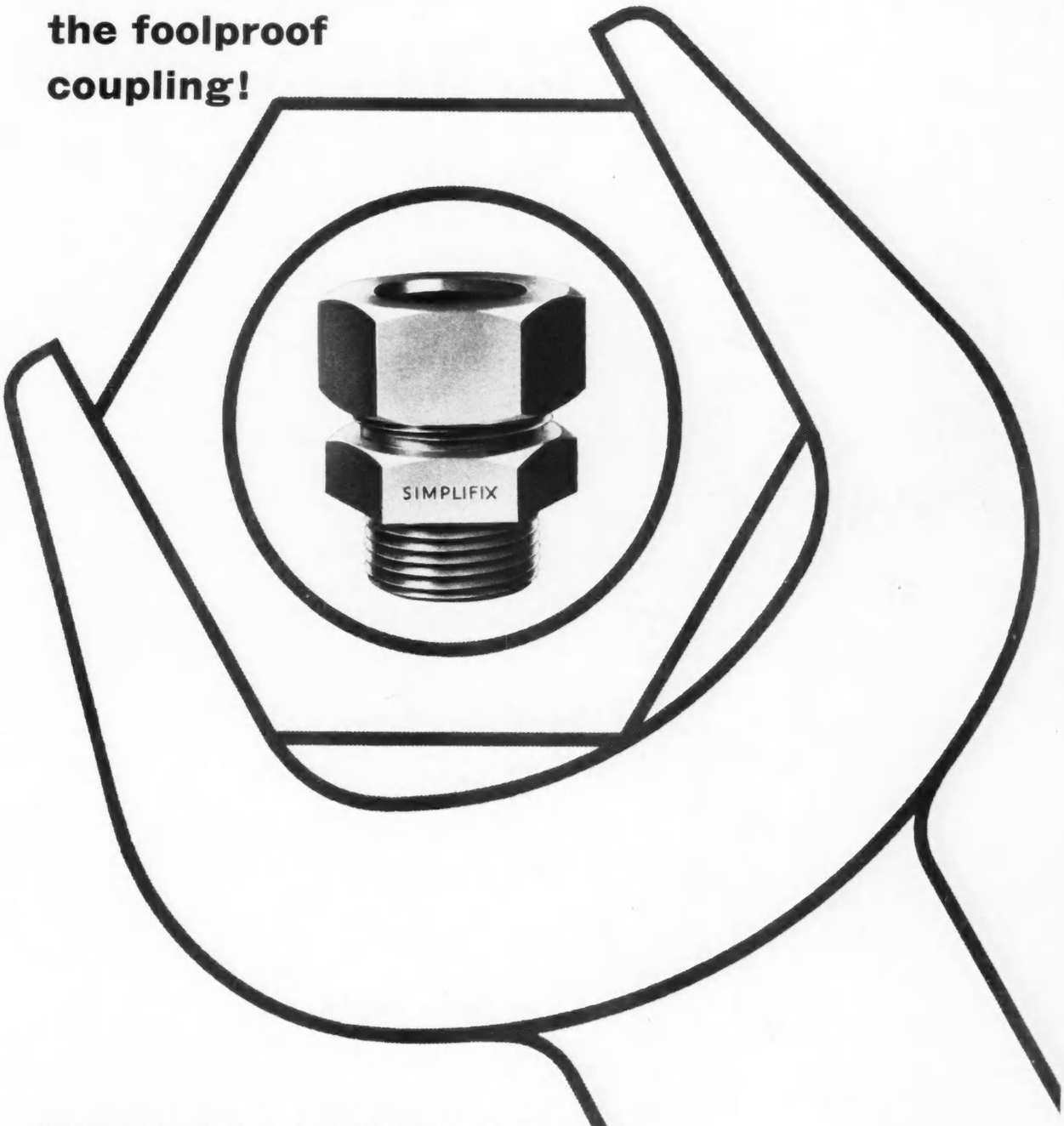

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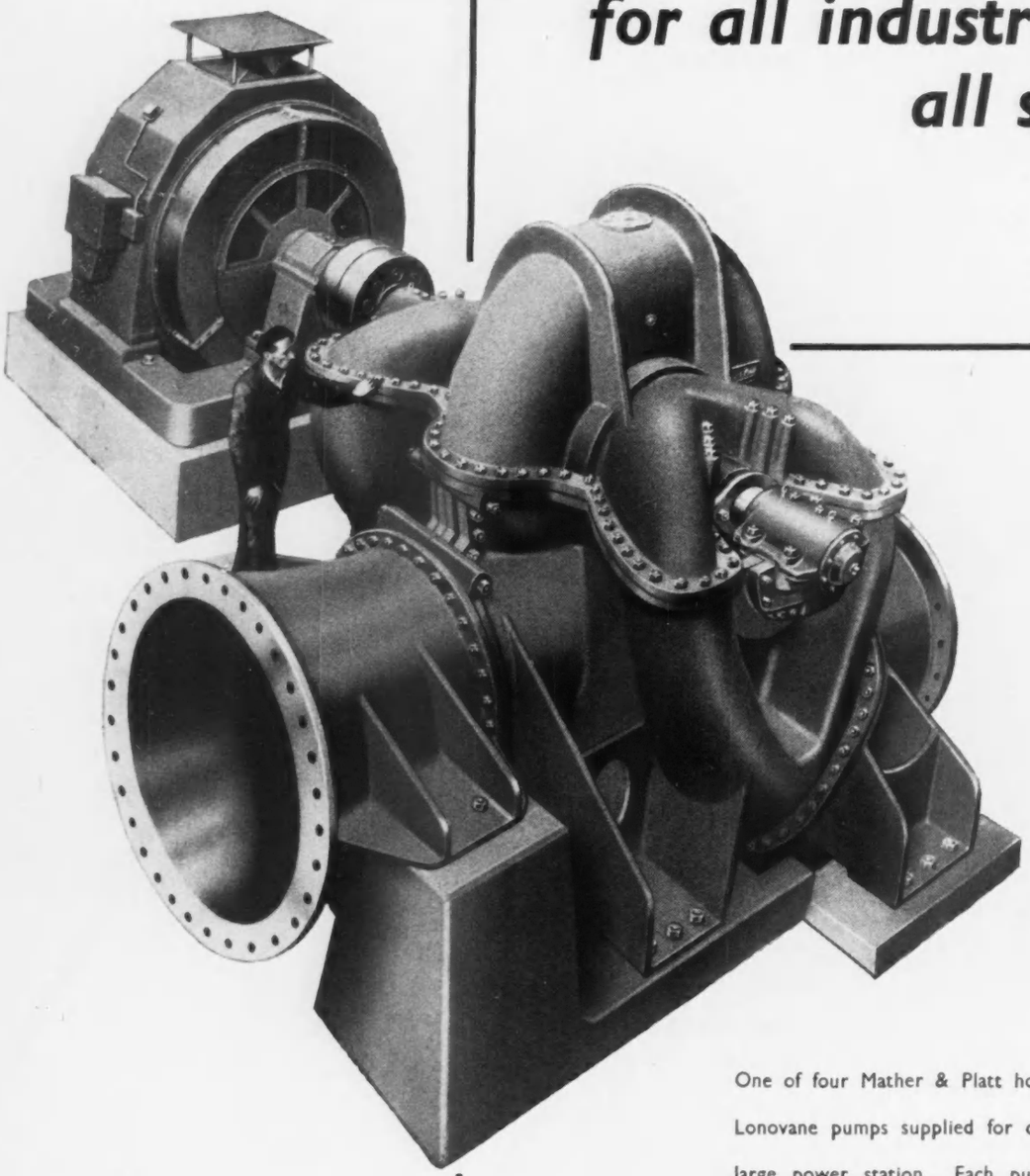

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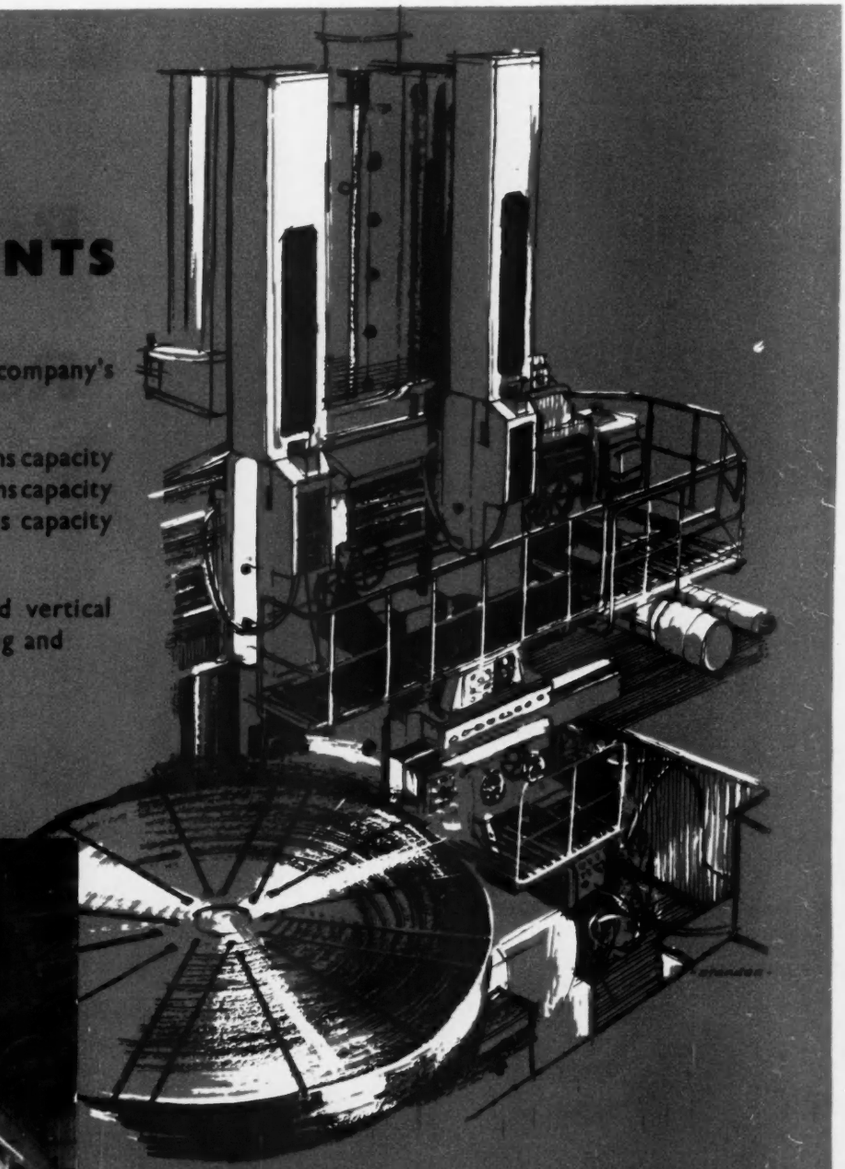
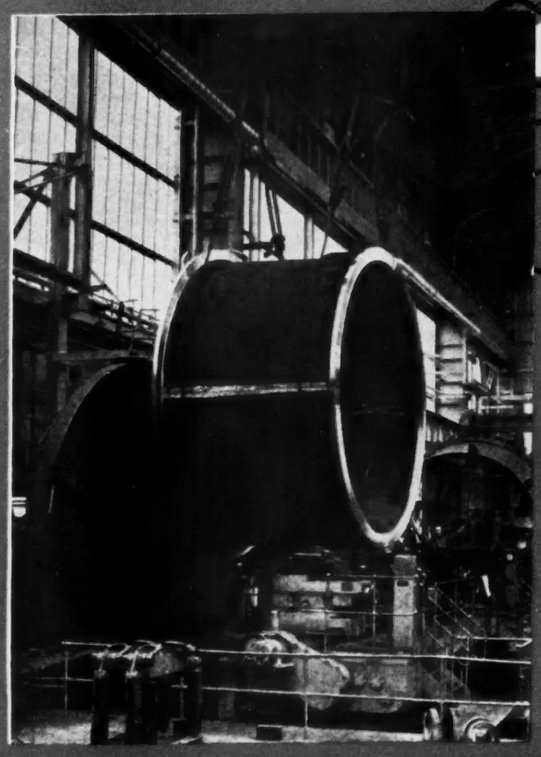


Berthiez borer 21' 0" swing x 11' 0" x 60 tons



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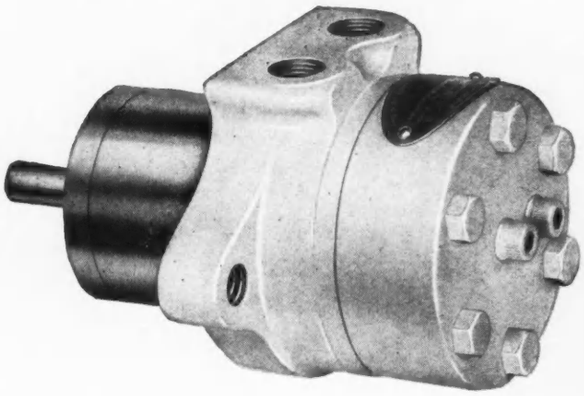

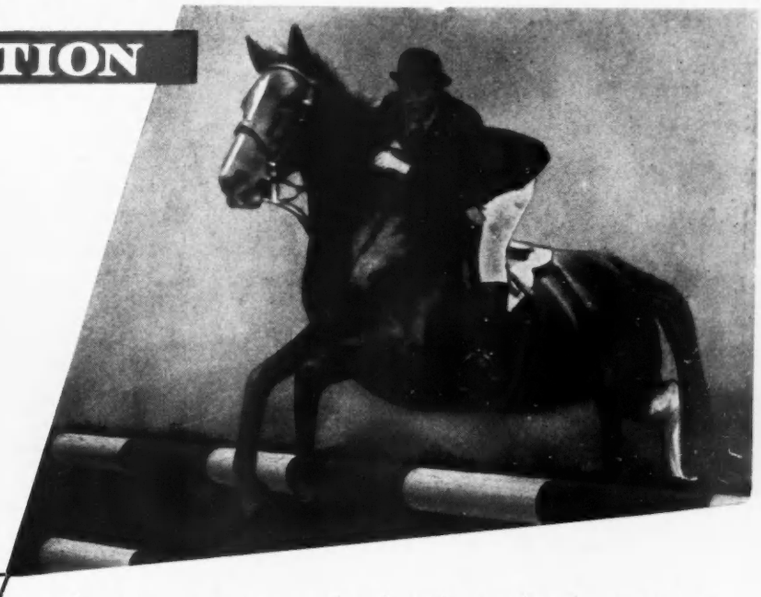

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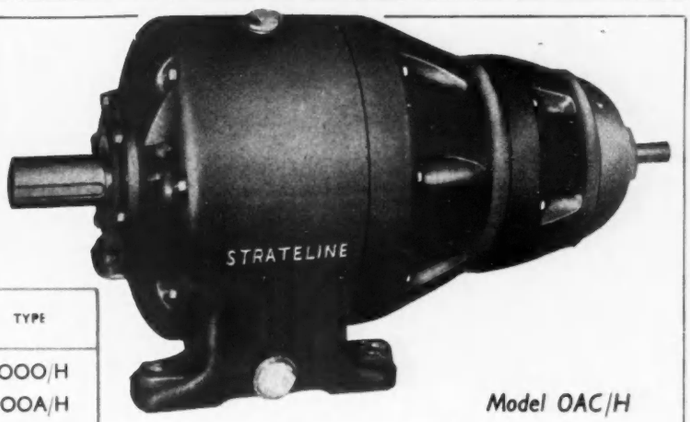

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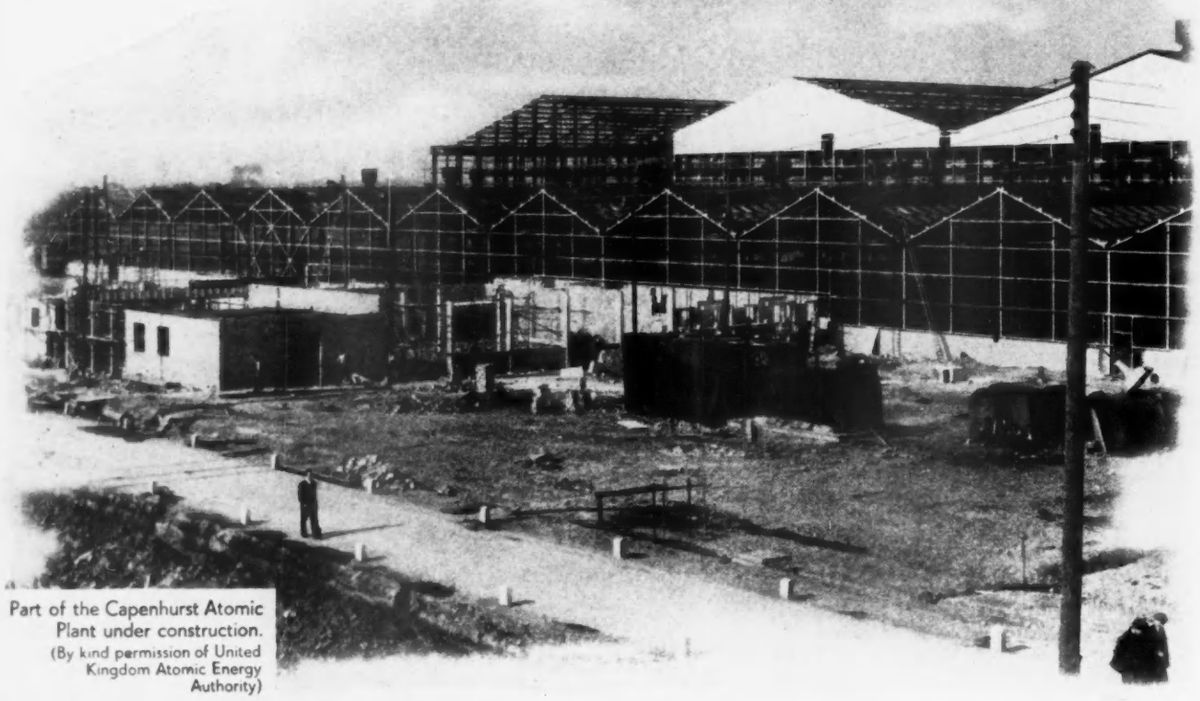

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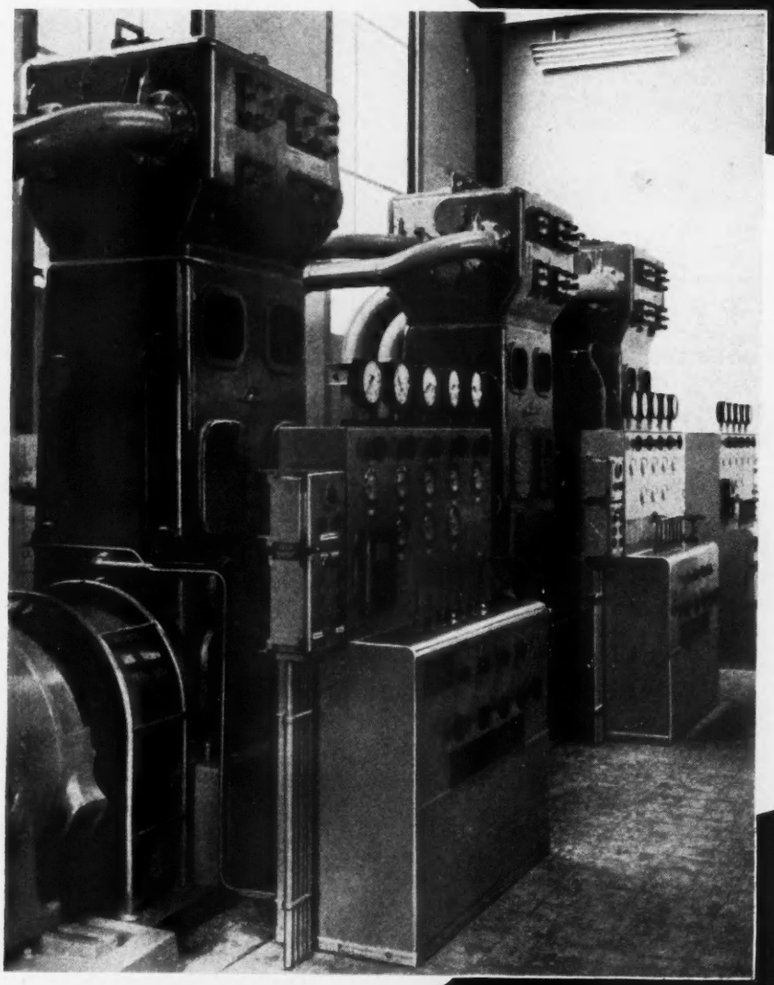

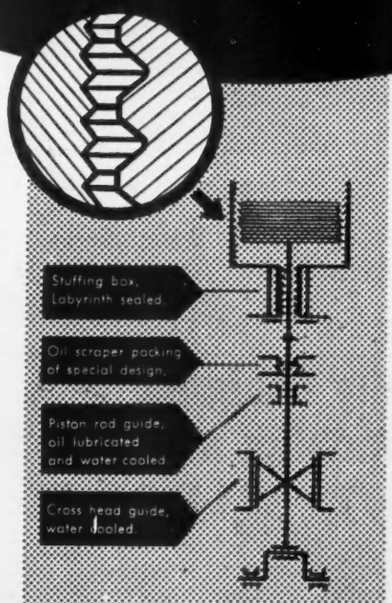
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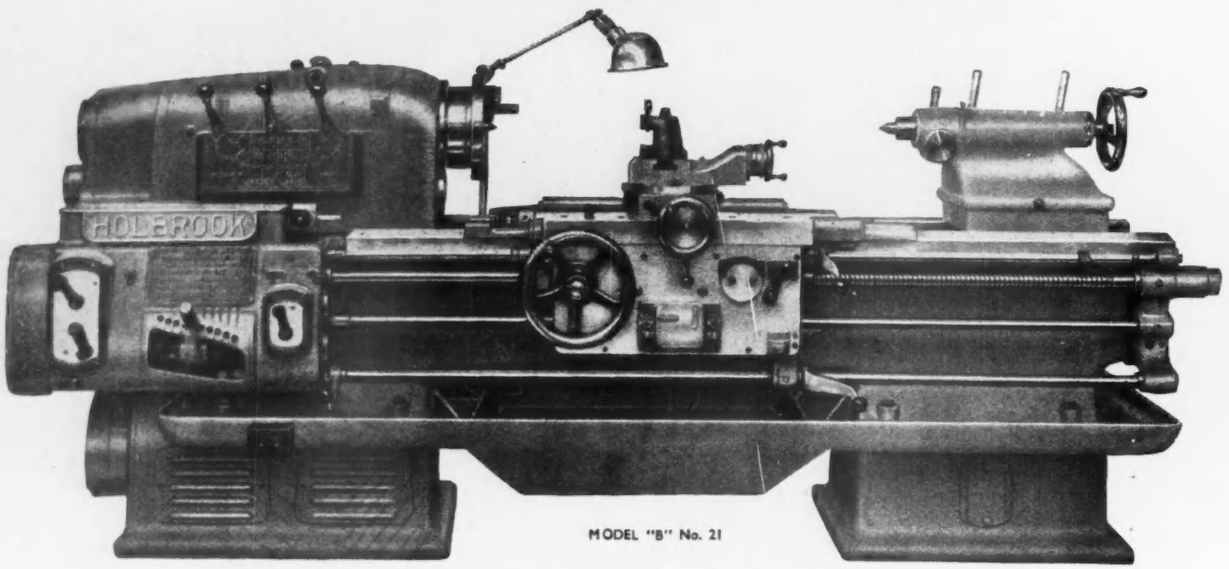

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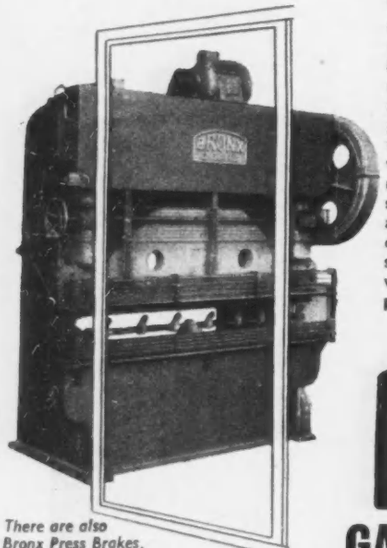

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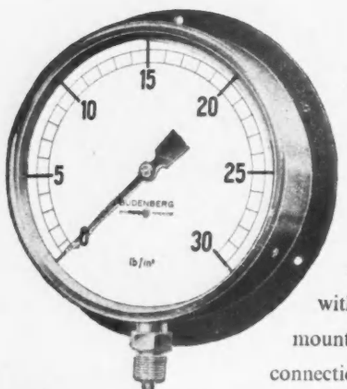

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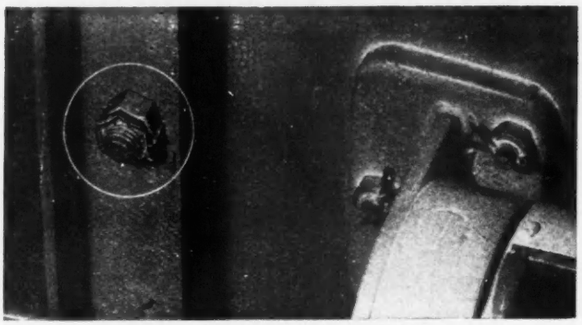

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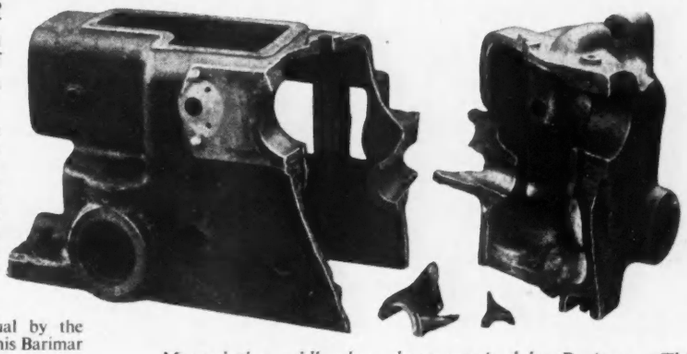

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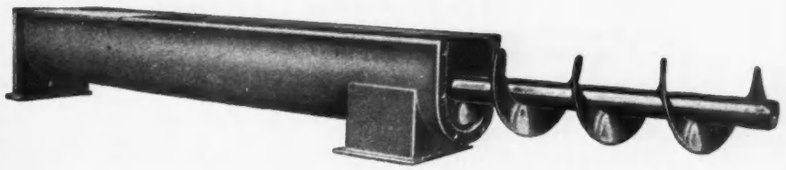

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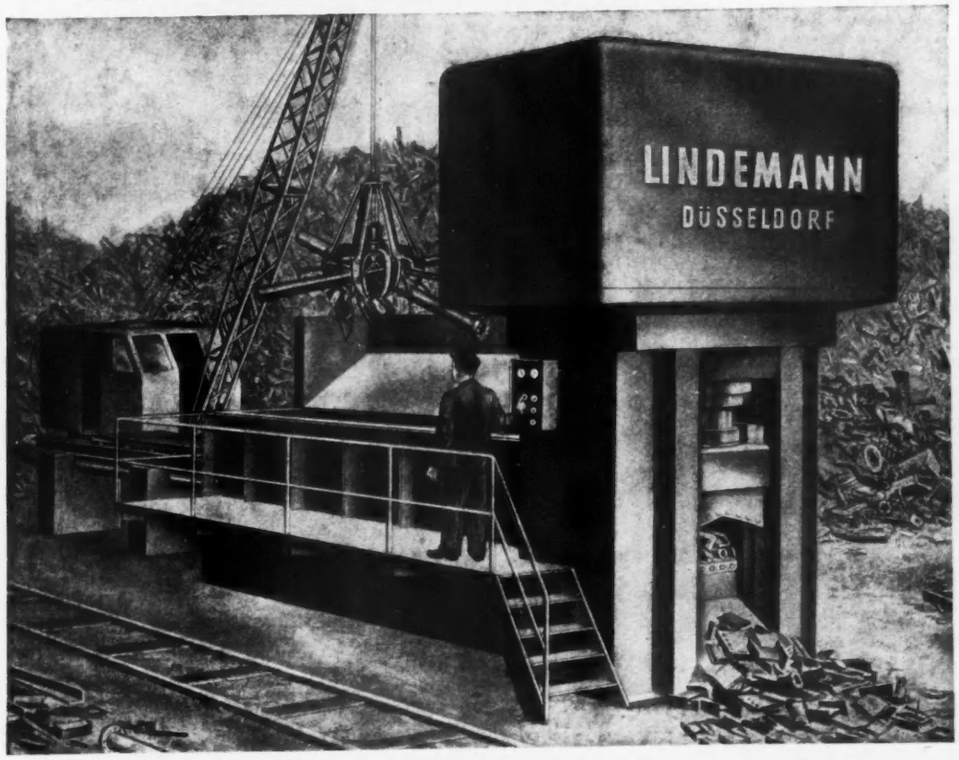

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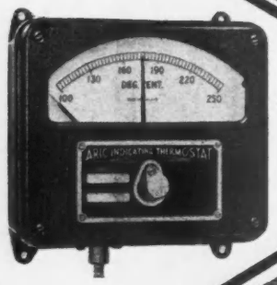

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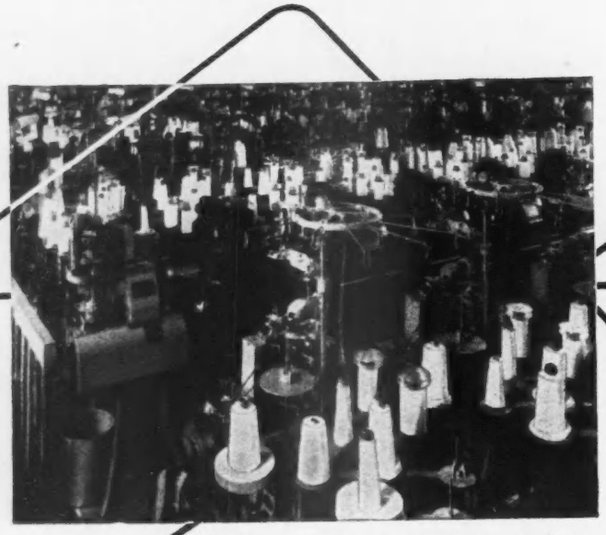

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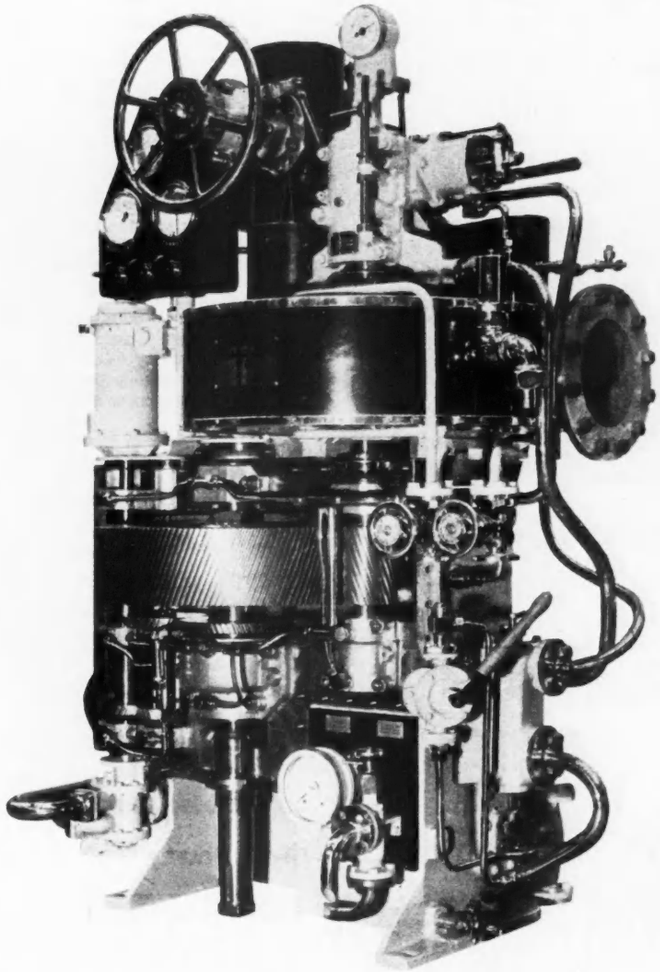

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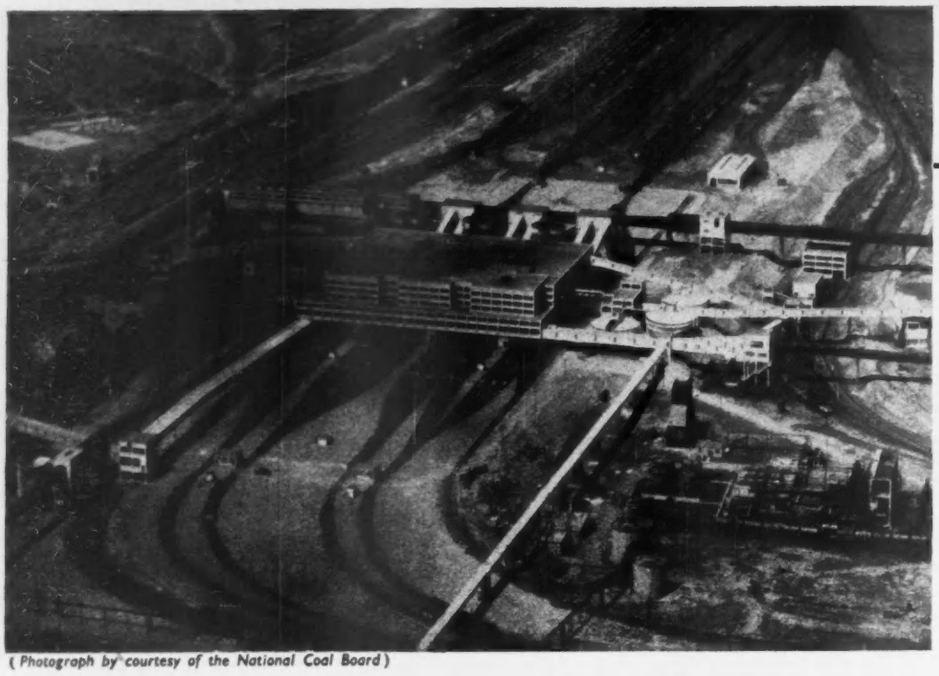

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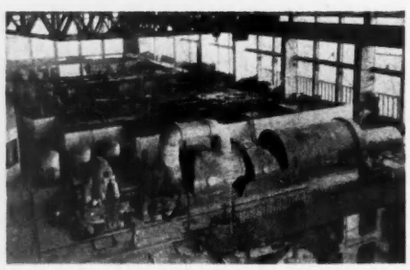

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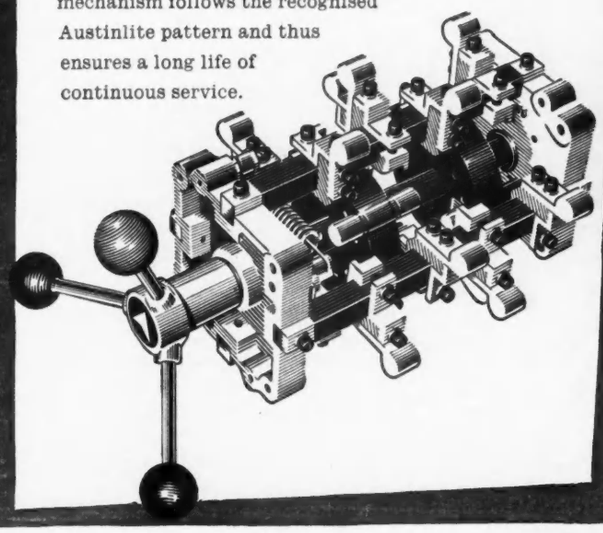

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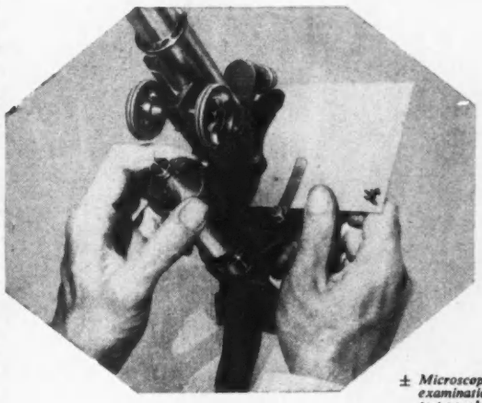

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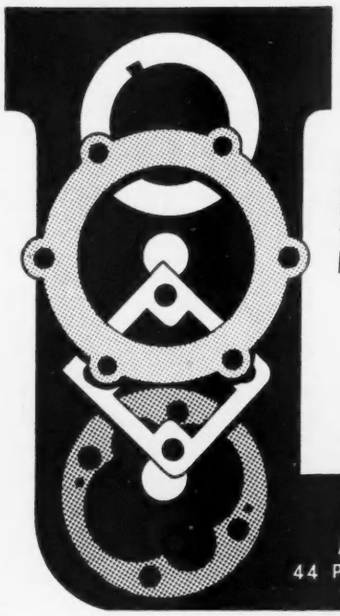

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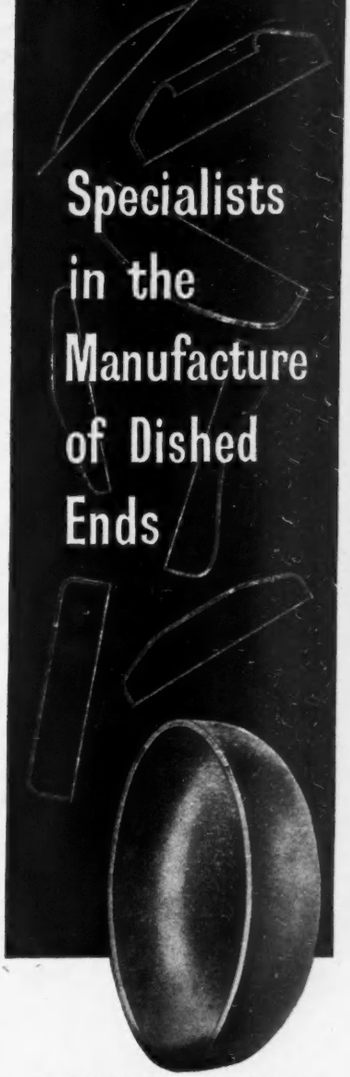

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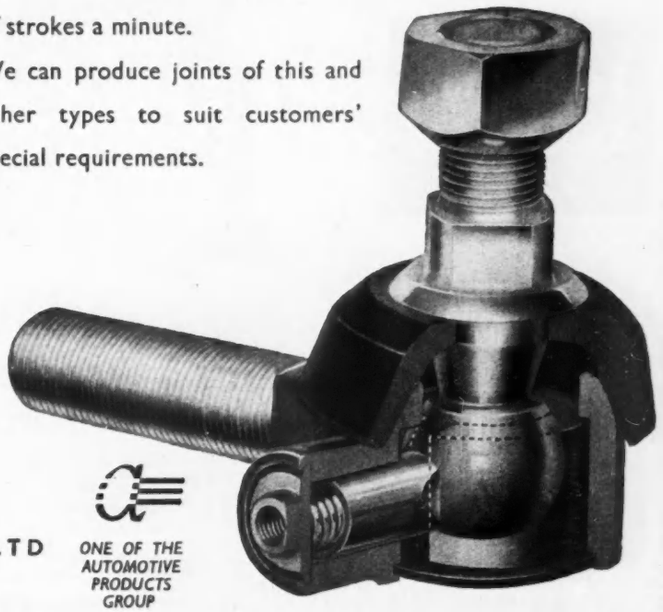

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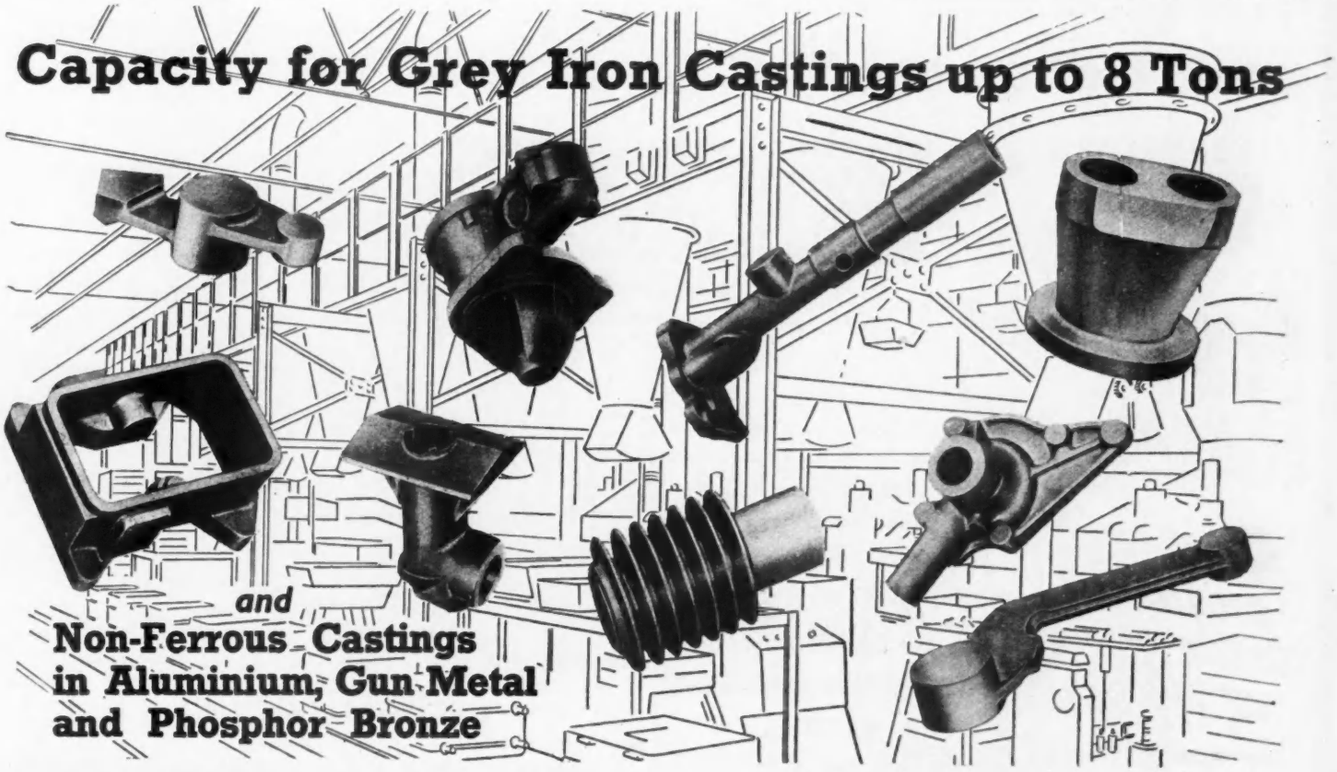

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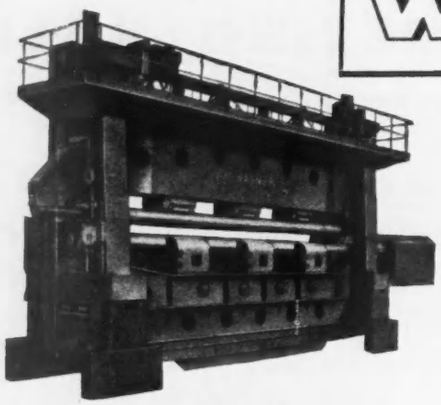

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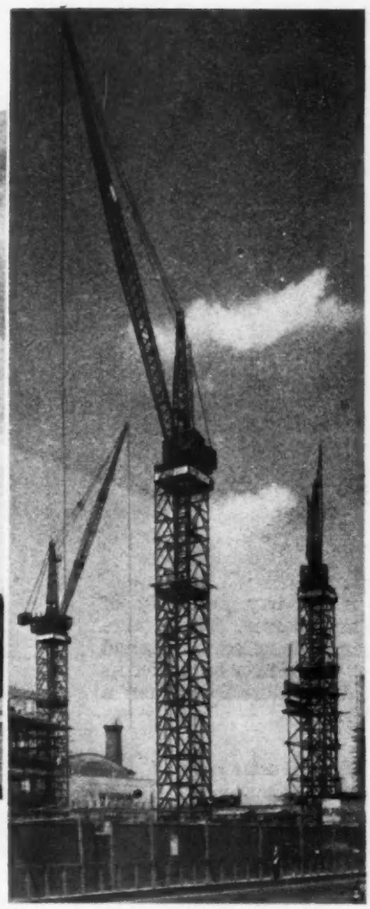

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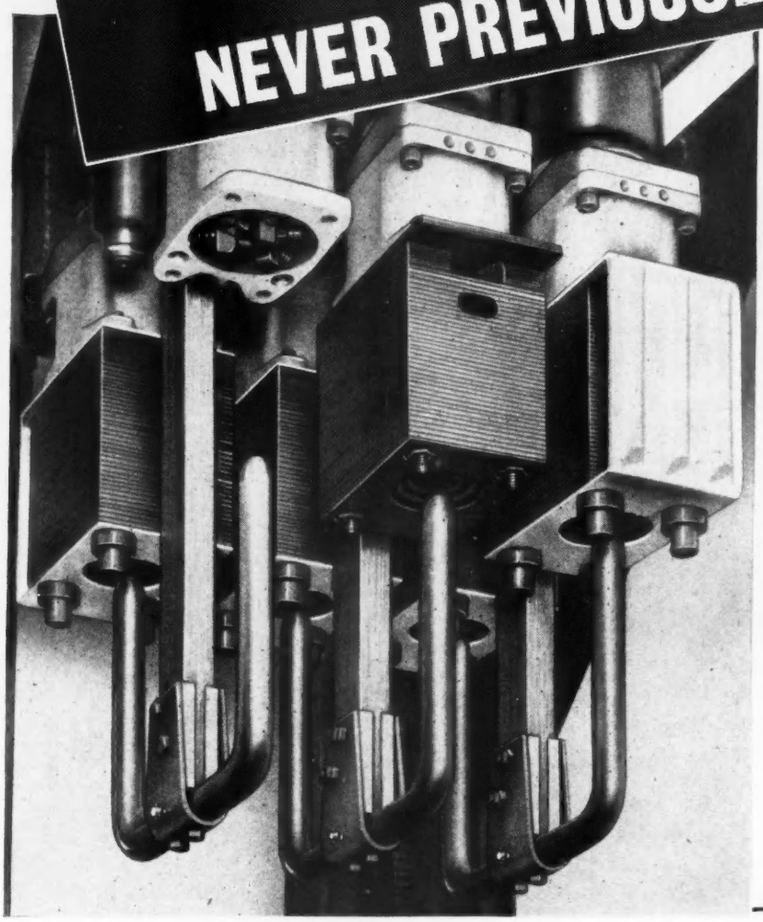

350 MVA Safety for 250 MVA 11 kV duty

The new Type PDB oil circuit-breaker is designed for use in J. & P. standard metalclad gear, which is of the size usually associated with 250 MVA, 11 kV gear, but it has been fully tested and certified for the following breaking capacities: 350 MVA at 11 kV; 250 MVA at 6.6 kV; and 150 MVA at 3.3 kV. A margin of safety greatly in excess of that previously offered, can now be enjoyed with standard metalclad switchgear **at no extra cost.**

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The 'FMmMD' and 'FMMD' meters comply with the B.S. Specification and have been approved by the Ministry of Power.

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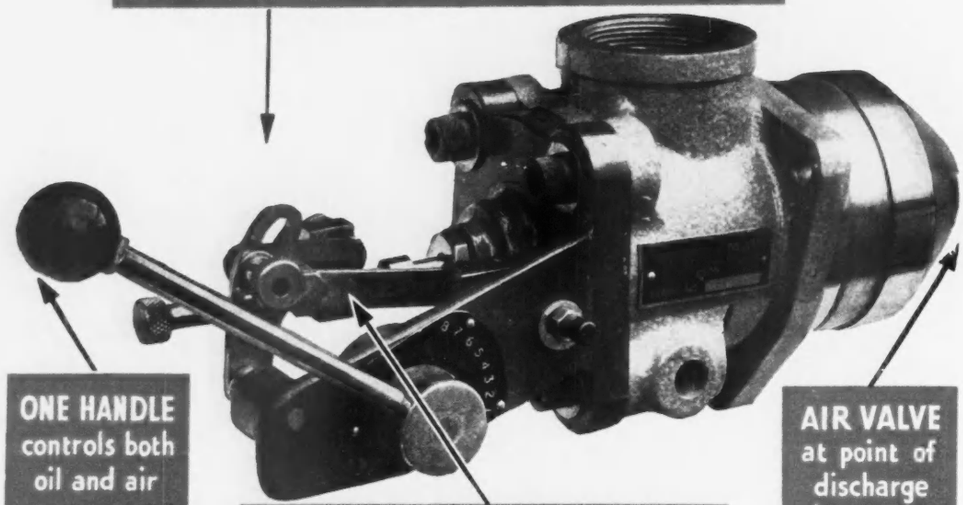

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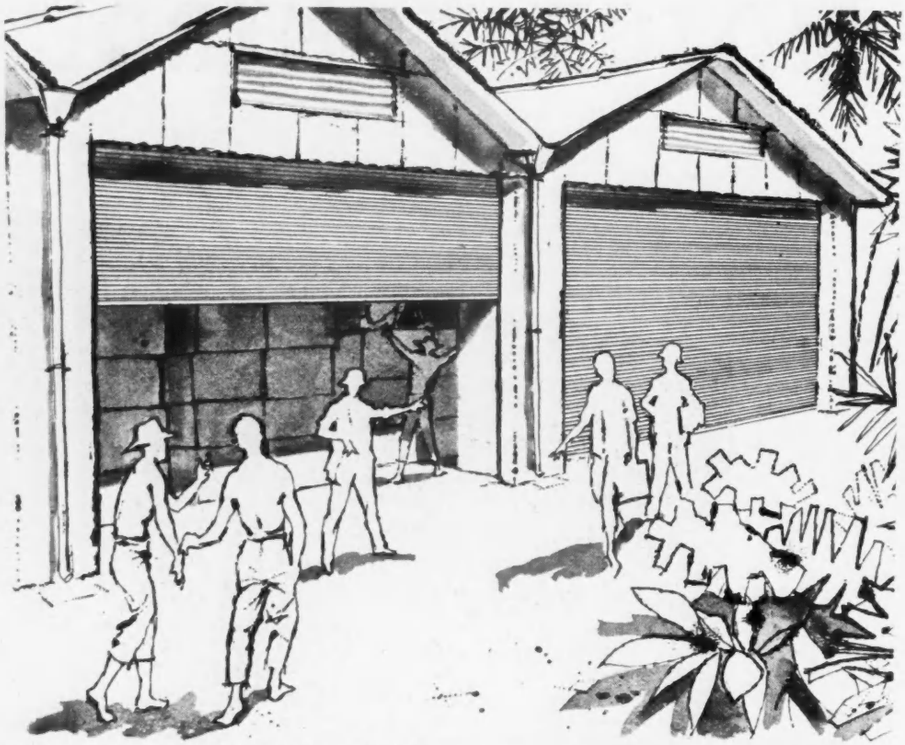

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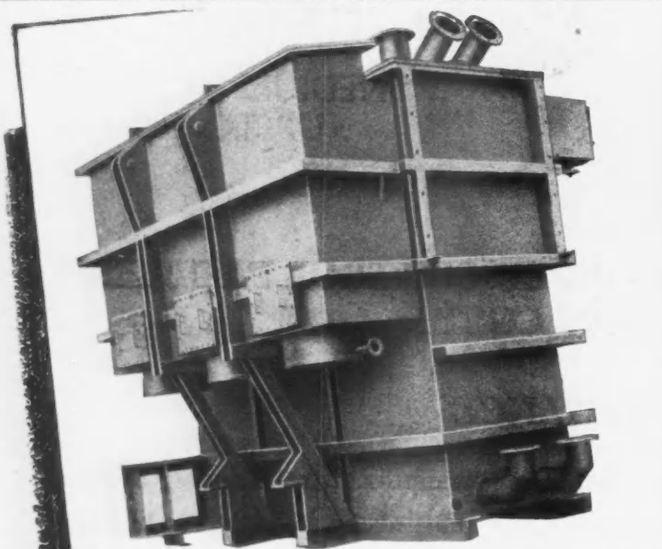

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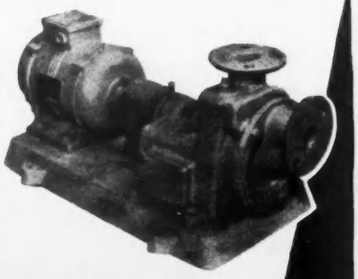

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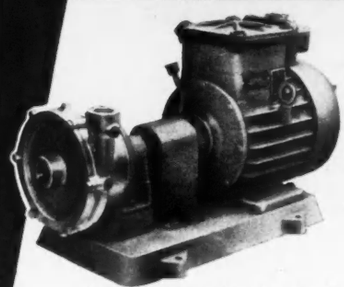

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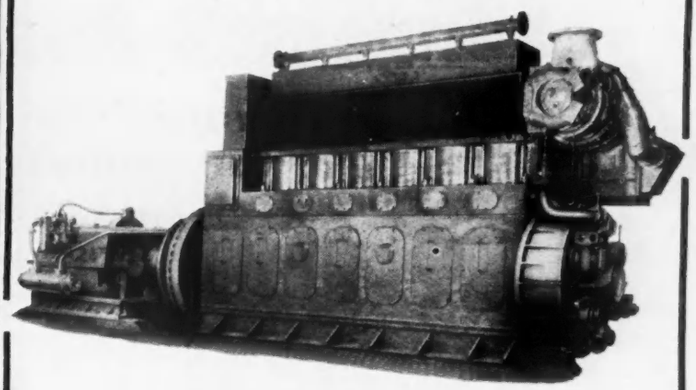

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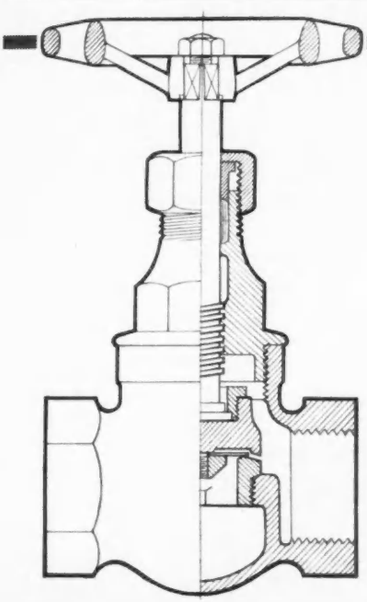
News from Hattersley



the Fig. 2016 'PRESEATOR' globe valve with the Flexible Titanium Disk*

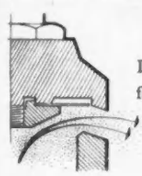
This specially designed Hattersley valve incorporates a flexible pre-seating disk made of an I.C.I. titanium alloy which is exceptionally resistant to corrosion and erosion. As this seats before the main surfaces, pipe-scale is trapped and the main seating surfaces protected from the effects of wire drawing.

The broad-faced clack and its seat are of differing compositions of nickel alloy, giving differential surface hardness which prevents galling and seizure. There are many other fine features in this new design valve.

Suitable for steam at 200 lb. per sq. in. and 500° F.

Please write for literature.

* *The Flexible Titanium Disk is protected by Patent No. 822147*



In open position free passage for flow directed across seating surfaces.

In 'Pre-shut' position flow and pipe scale held back by *Flexible Titanium Disk.*
Patent No. 822147

Valve fully closed. Seating surfaces have passed through wire-drawing zone under virtually 'no-flow' conditions.

Over a period of years the outstanding merits of this Valve have been proved under the most arduous service conditions on many installations.

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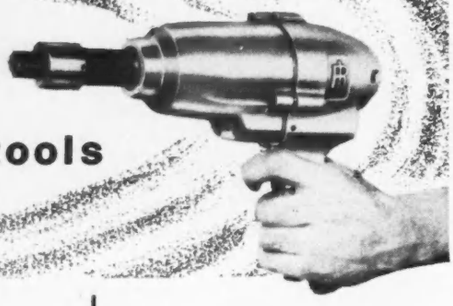

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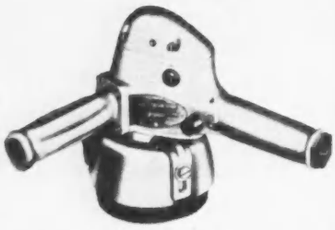

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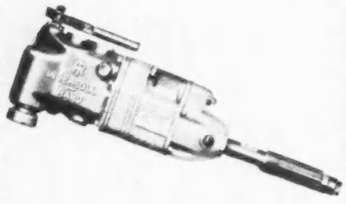

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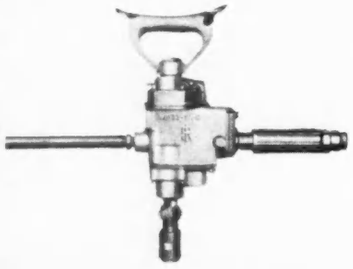

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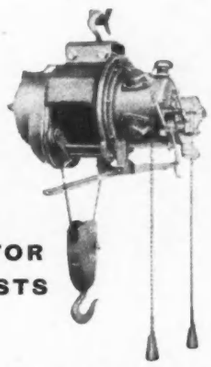

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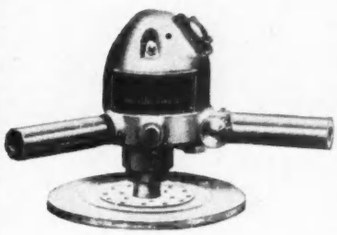

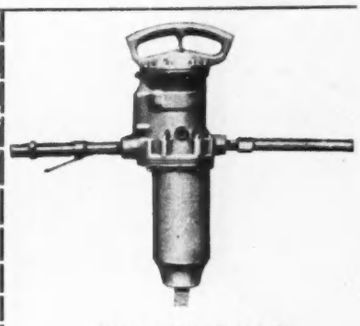

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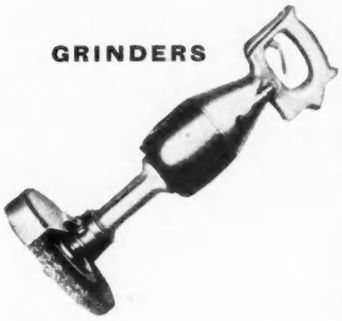

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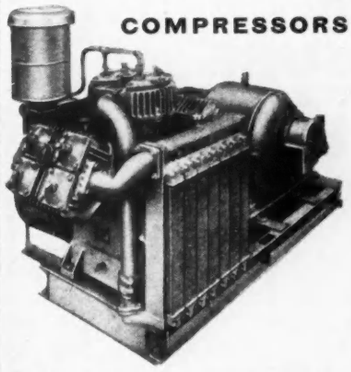

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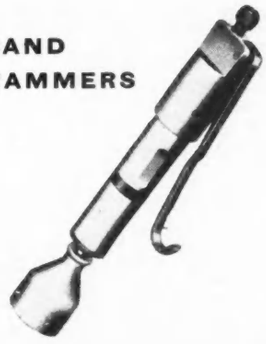

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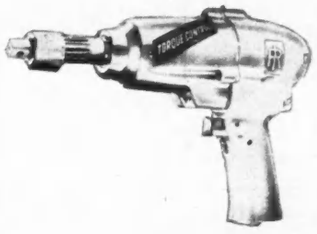

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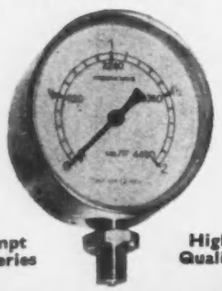

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"You can't half tell the difference, can't you, Puss?"

"**Purrrr!**"

"Since they fitted L & C Piston Rings, I mean"

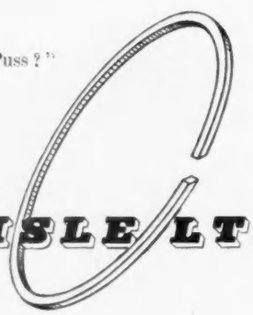
"**Purrrr!**"

"Engines runnin' as sweet and smooth as a bowl o' cream, ain't they?"

"**Purrrr!**"

"How would you sum up these L & C rings, Puss?"

"**Purr-fect!**"



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Manufacturers of the well known "Patent Double Action Piston Rings" for steam engines

MAKERS OF THE WORLD'S FINEST DIESEL PISTON RINGS

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a range of precision ground case-hardened gears

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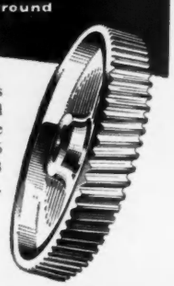

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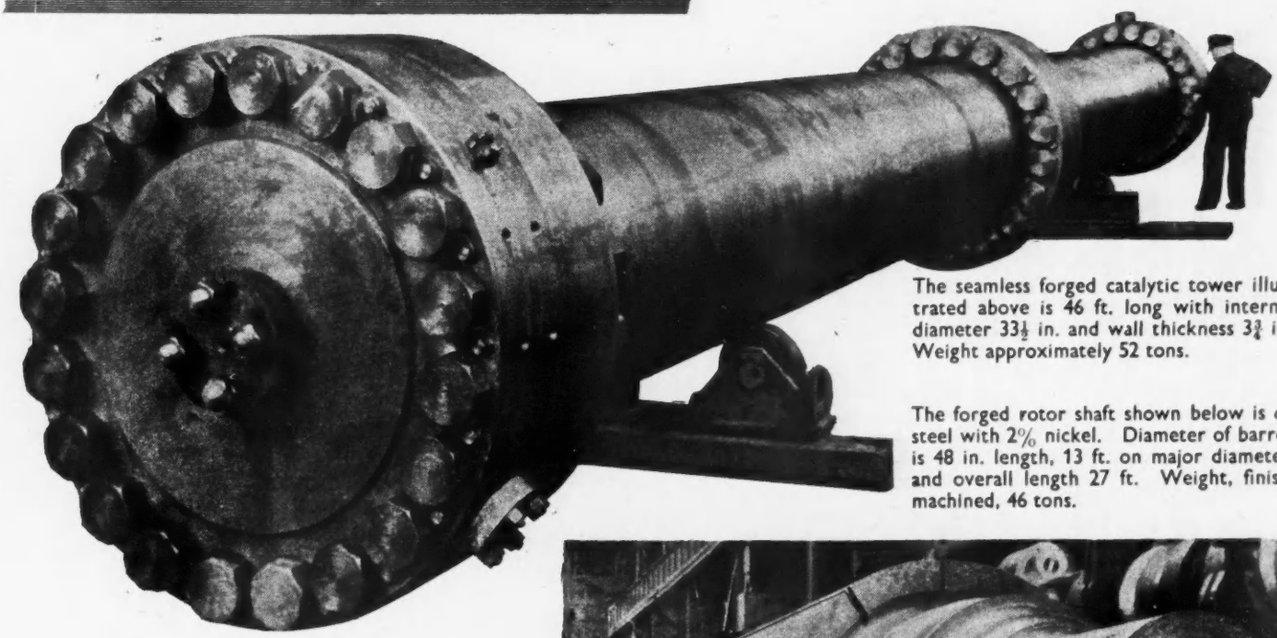
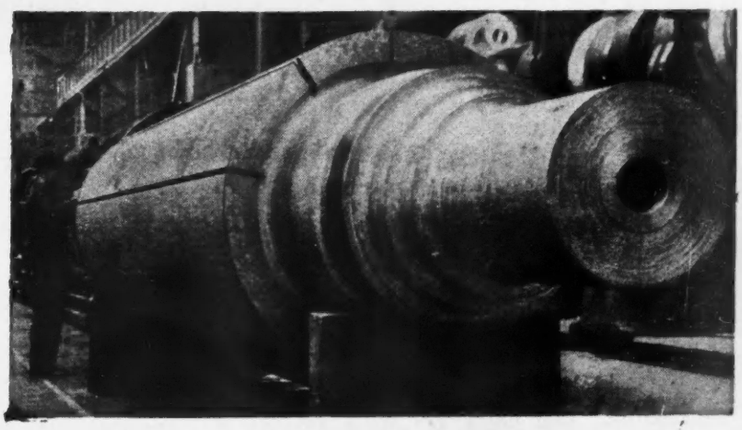
RUHRSTAHL FORGINGS AND STEEL CASTINGS



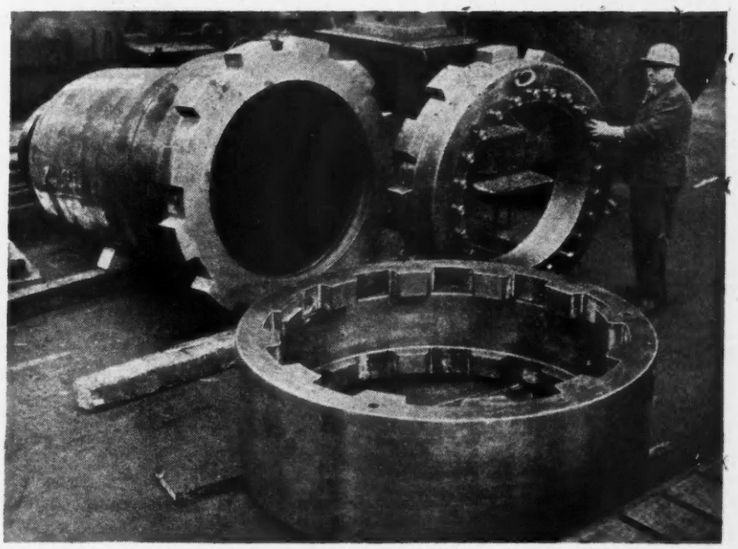
The seamless forged catalytic tower illustrated above is 46 ft. long with internal diameter 33½ in. and wall thickness 3¾ in. Weight approximately 52 tons.

The forged rotor shaft shown below is of steel with 2% nickel. Diameter of barrel is 48 in. length, 13 ft. on major diameter and overall length 27 ft. Weight, finish machined, 46 tons.



Forgings up to a maximum ingot weight of 195 tons can be supplied in all states of finish from "black forged" to finish machined. Steel castings up to 245 tons after fettling and castings of the largest dimensions can be supplied and, if required, can be part or finish machined.

The autoclave illustrated below is of chrome molybdenum alloyed cast steel for a working pressure of 2,414 p.s.i. and controlled temperature 572°F. The largest diameter is 5 ft. 7 in. and height 9 ft. 7 in. Total weight approximately 22½ tons.



This cast steel boss for a Kaplan turbine is 10 ft. diameter × 9 ft. The servomotor cylinder is cast on. Weight approximately 42 tons.

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HALIFAX HOUSE, STRAND, LONDON W.C.2.
Telephone Trafalgar 7224
Also at BIRMINGHAM Phone Midland 3431 and GLASGOW Phone Central 0922

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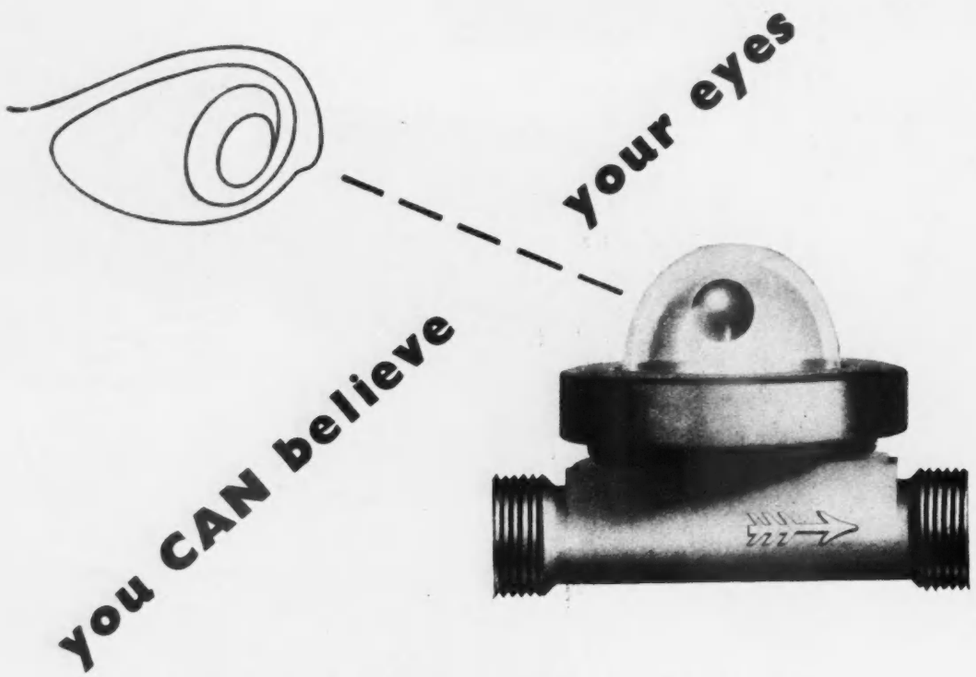

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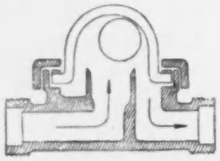

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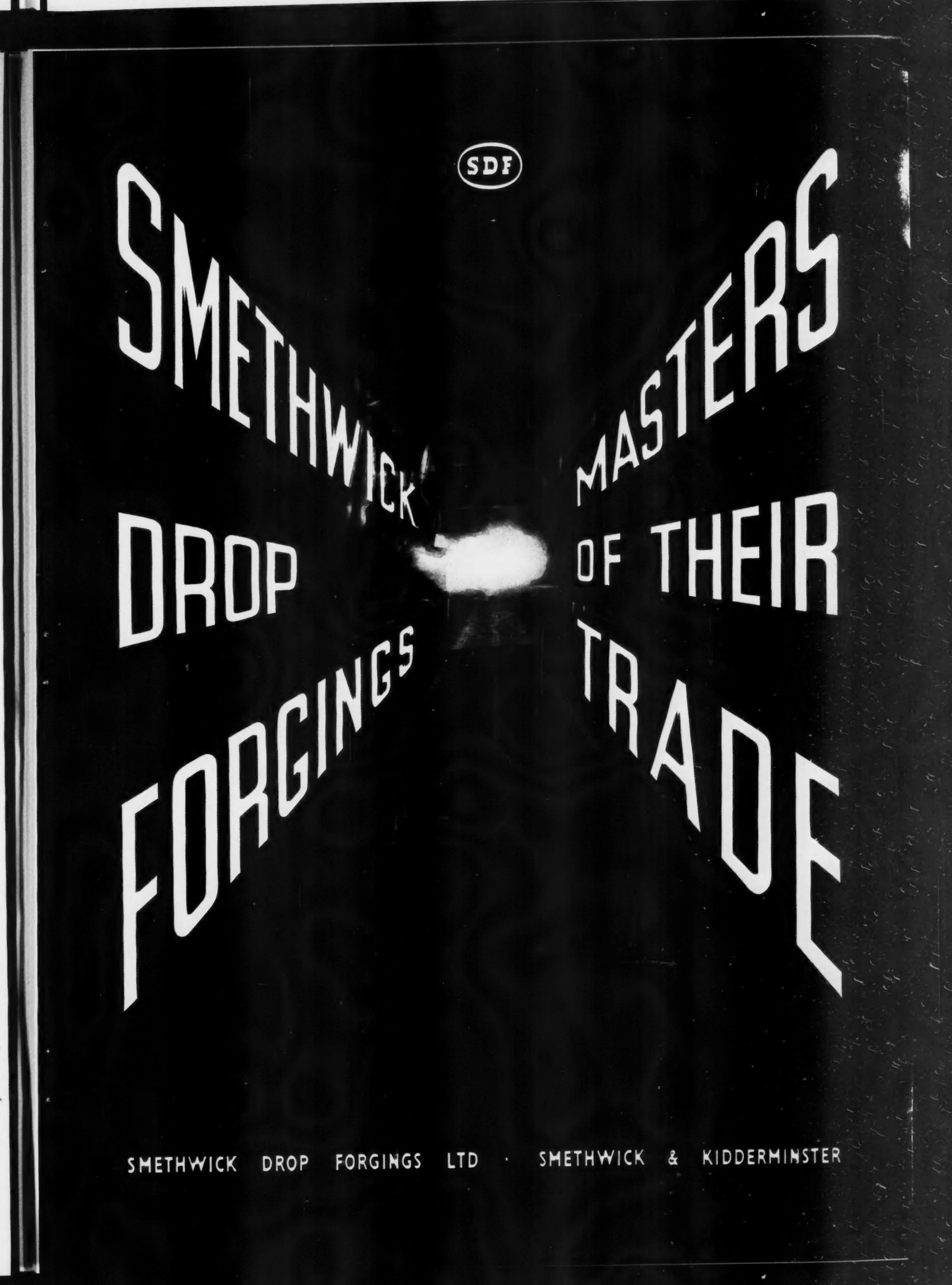
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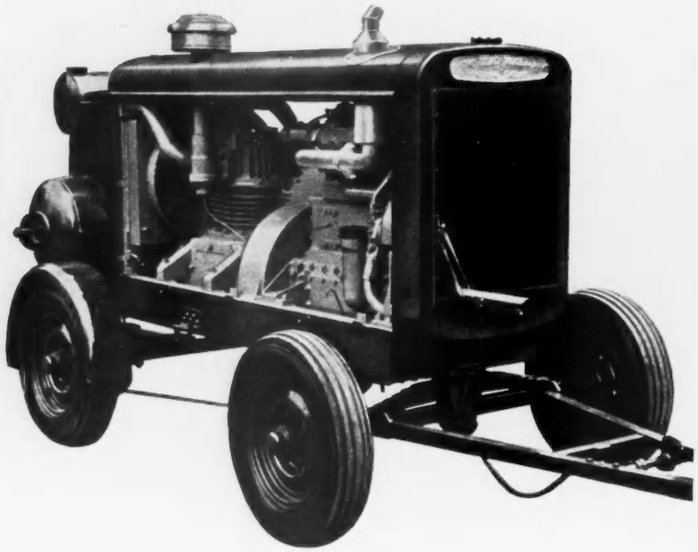

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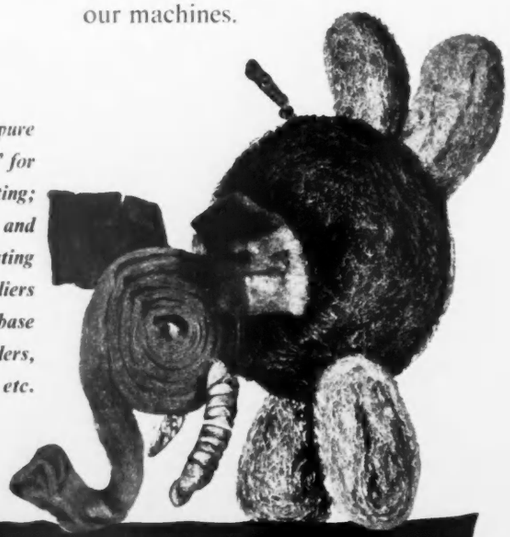

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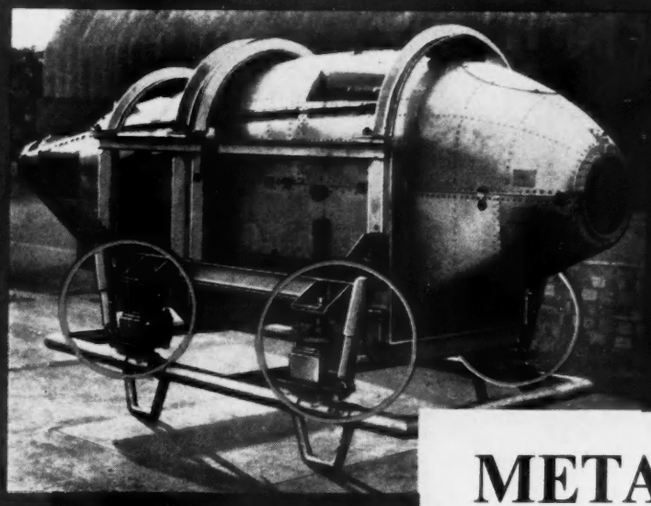

Transit Stand by T. Scudery Ltd., with Metalastik Shock Mounting System. The unit shown is the container for the de Havilland Super Sprite A.T.O. rocket engine.

METALASTIK systems

for protecting engines and equipment from shock and vibration in transit

The illustration above shows the main Metalastik units in a Metalastik shock protection system in conjunction with supplementary shock absorbers.

Another type of shock mounting designed to carry static loads of 75-150 lbs. when the G factor has to be reduced to between 10 and 20 under Ministry tests. No supplementary shock absorbers are required. Although a deflection of 4" is obtainable under 1,200 lbs. the mounting is only 5⅛" high.

(Patent applied for)

This system enables manufacturers to meet all the requirements of the Ministry of Supply specification D.E.F. 1234.

Compared with arrangements depending entirely on rubber or steel springs, this system needs only half the deflection for the same amount of shock absorption; the packing case may therefore be smaller.

Conversely, the Metalastik system, *for the same amount of travel,* provides far greater shock absorption than is obtainable with any kind of unassisted spring arrangement.

Our experience in designing shock mounting systems, and in testing to Ministry specifications, is at the disposal of customers and we will be glad to advise on stand construction and associated problems.

(Patents applied for)

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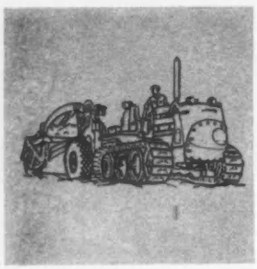
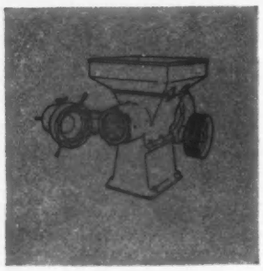
Cement Plant

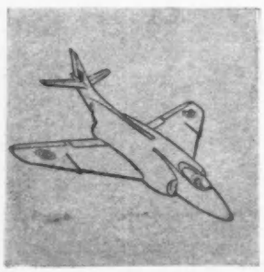
Eastwoods Ltd., Barrington Works.

In the design of machinery to withstand the arduous operating conditions met with in Cement Plants, Vickers-Armstrongs can draw on an outstanding background of engineering achievement. History-making aircraft like the Viscount and Vanguard . . . fast ocean liners such as the new Canadian Pacific 'Empress of England' and super-tankers like the 'Spyros Niarchos' . . . these are headline news. Yet, in their own fields, hundreds of lesser-known products of Vickers-Armstrongs are equally important. Whether complex or simple, each shares the same background of outstanding design and sound construction; each solves critical engineering problems.



For many years Vickers-Armstrongs have specialised in the design and manufacture of efficient and dependable Cement Plant. For machinery designed to operate continuously for months on end, under arduous conditions, robust and ample construction is essential. In Vickers-Armstrongs' designs, all parts are liberally rated for long working life and minimum maintenance. Equipment on any scale is designed and built for both wet and dry process plants, and includes kilns, mills, crushers, mixers, rolls, feeders, coolers, dryers and the manufacture of cement and raw meal pumping plant. Complete installations and individual machines are now in successful operation all over the world.





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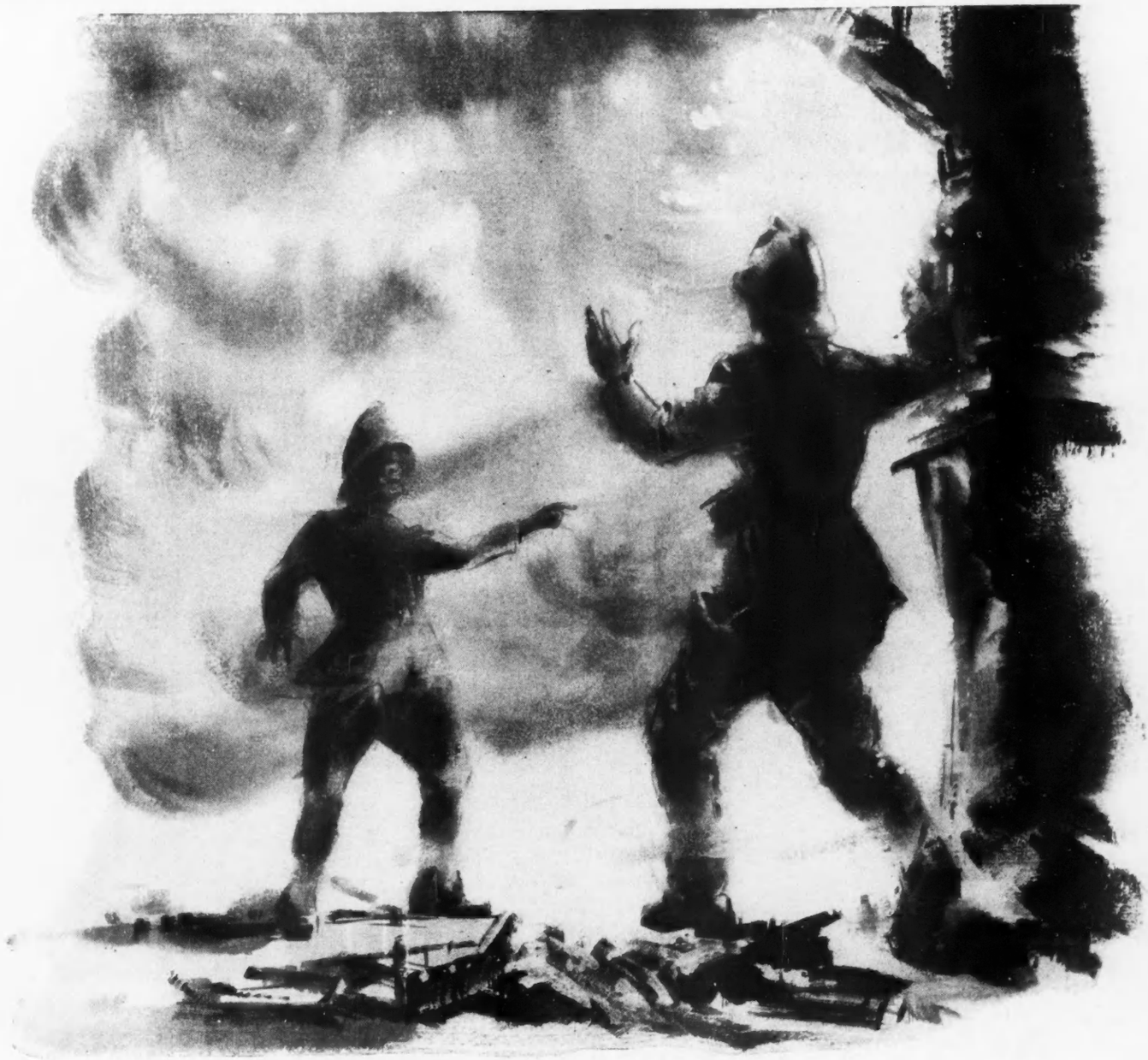

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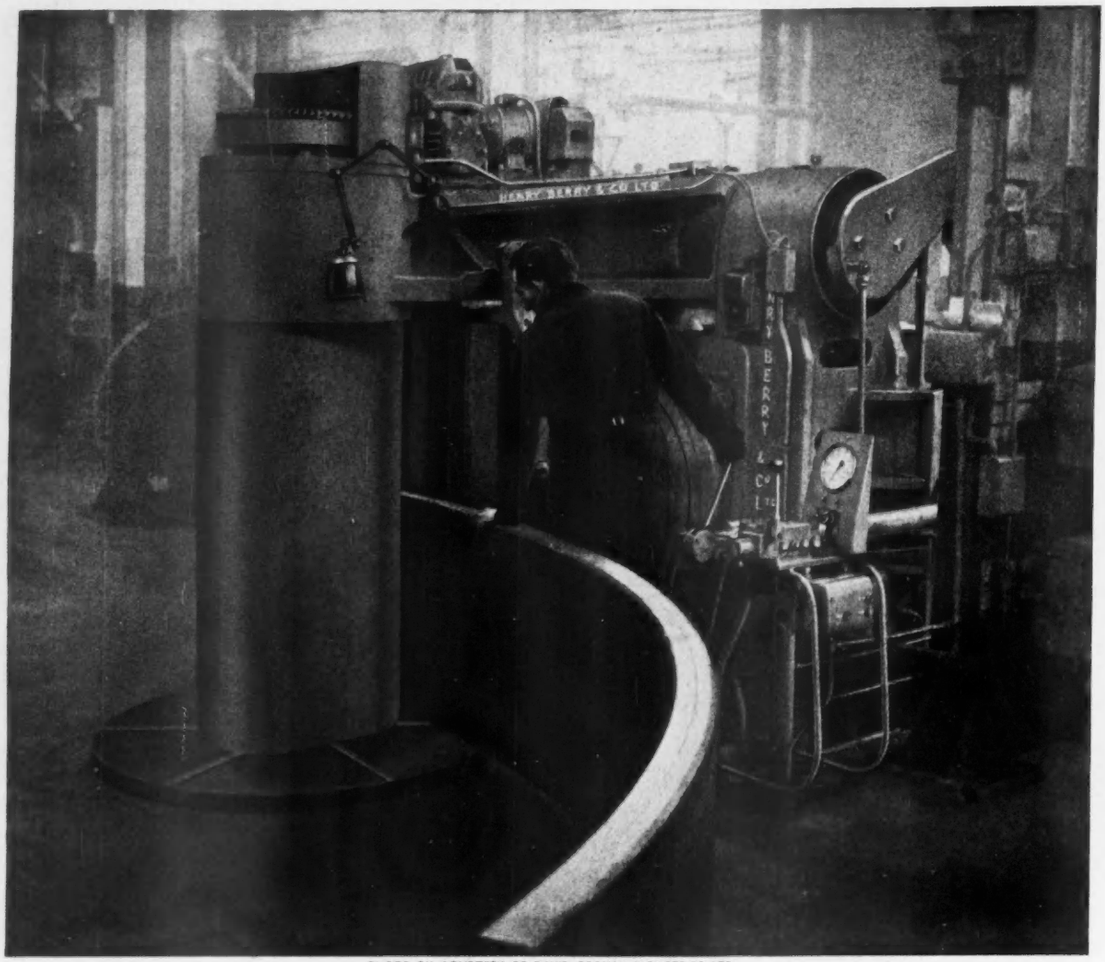

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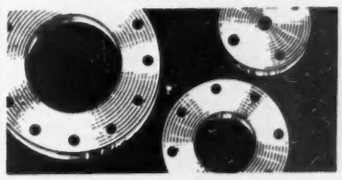

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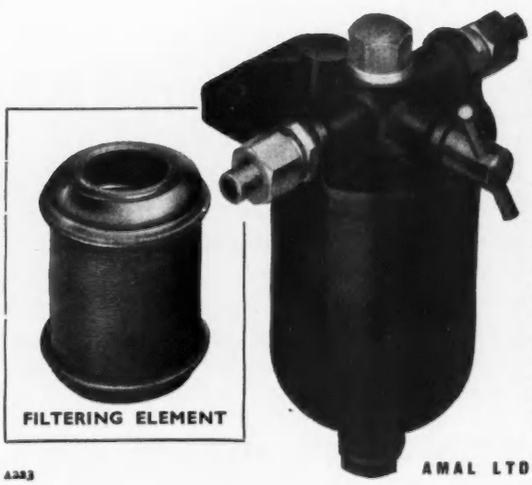

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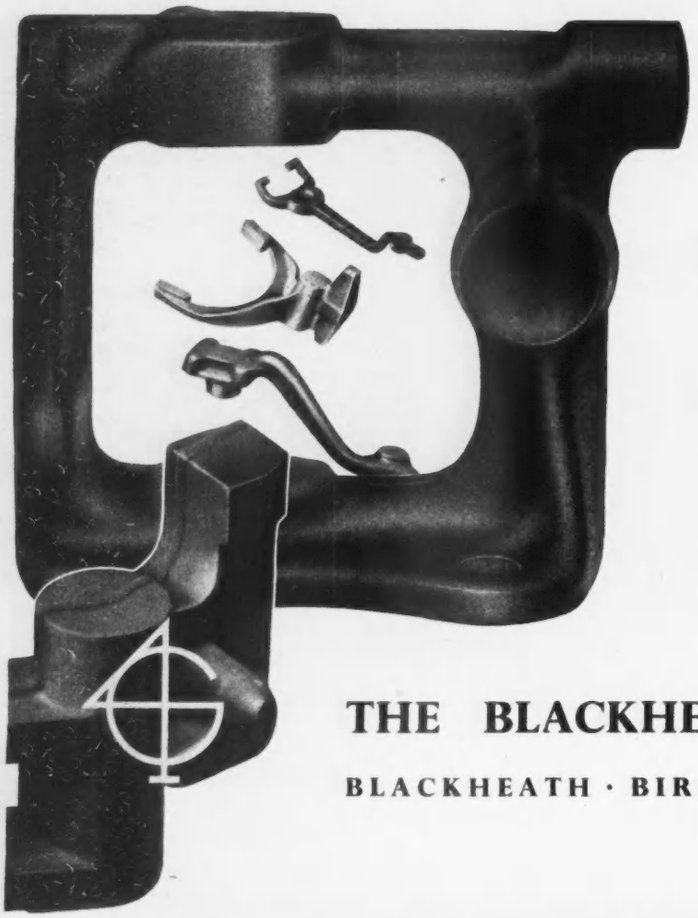

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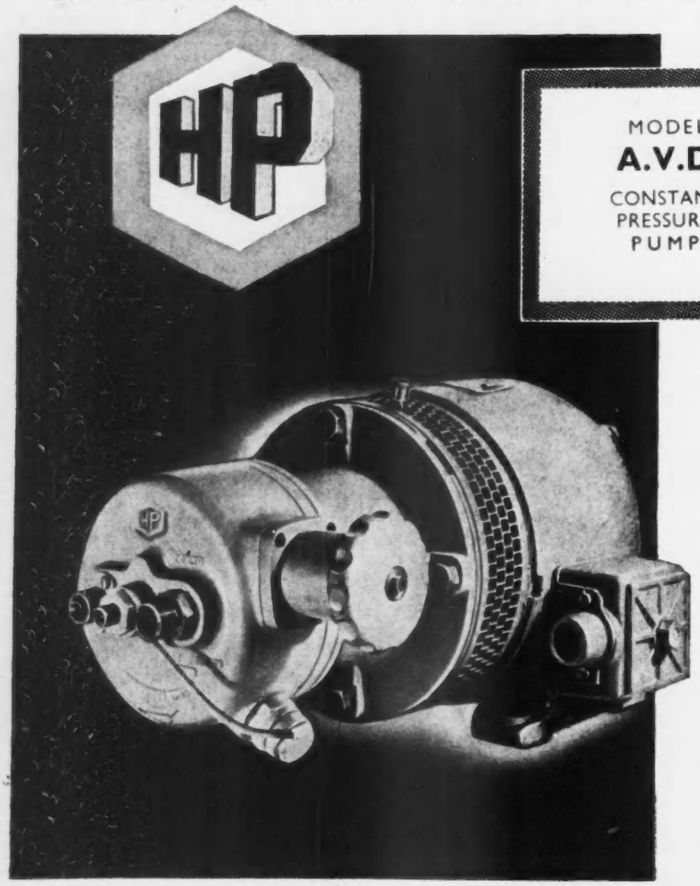

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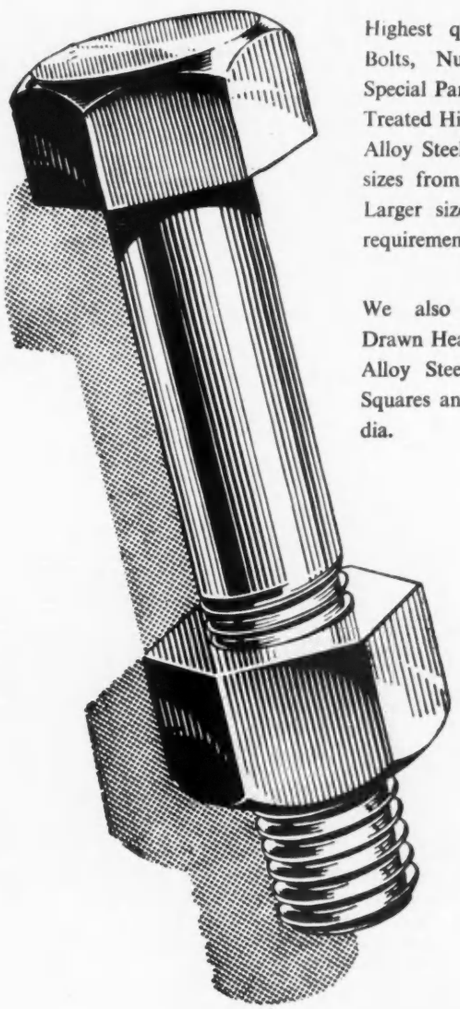

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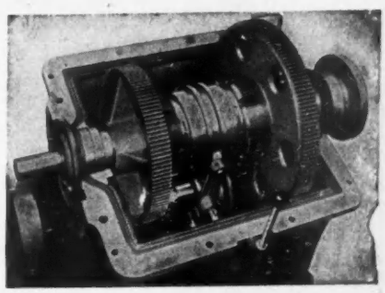

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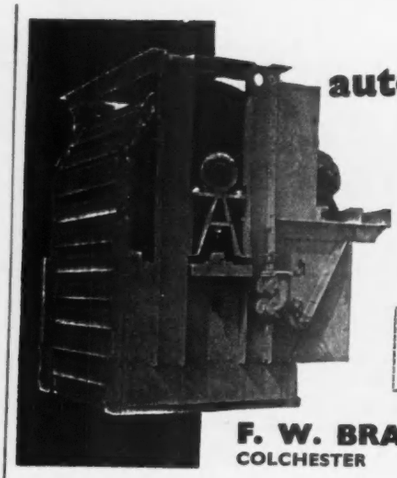

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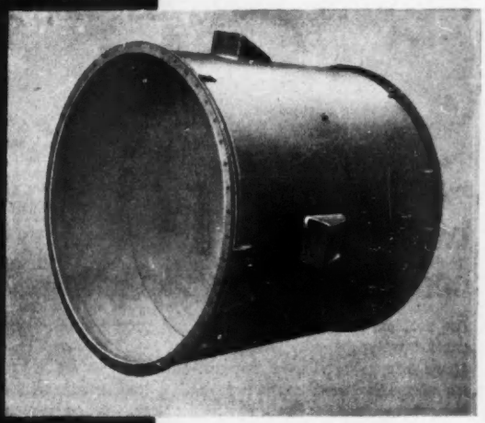

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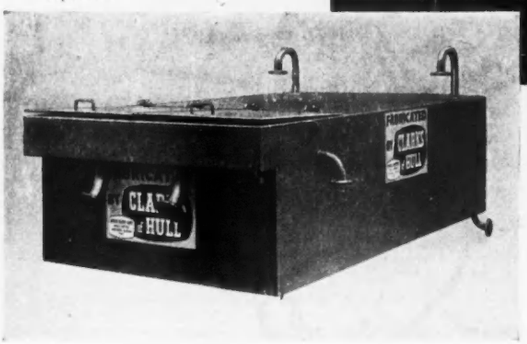

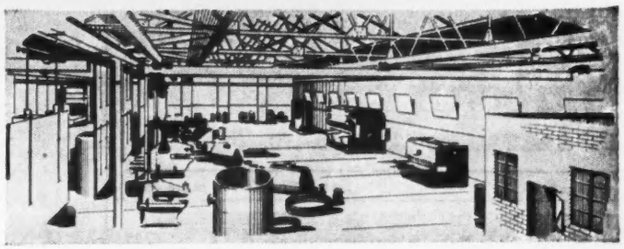

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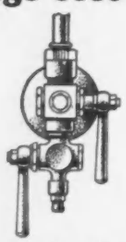

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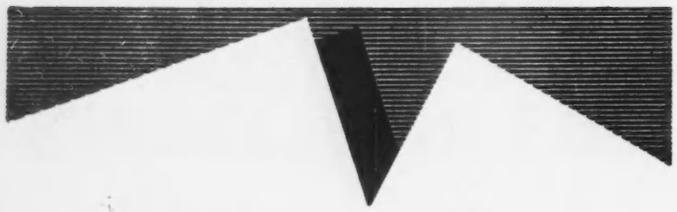

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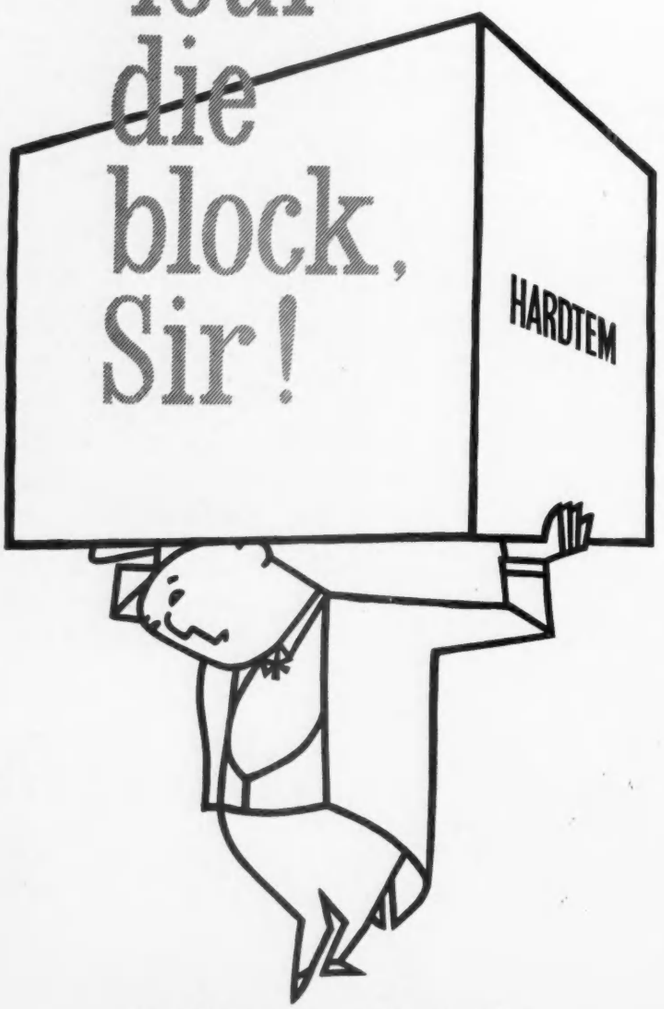

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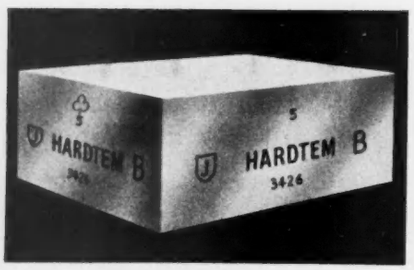

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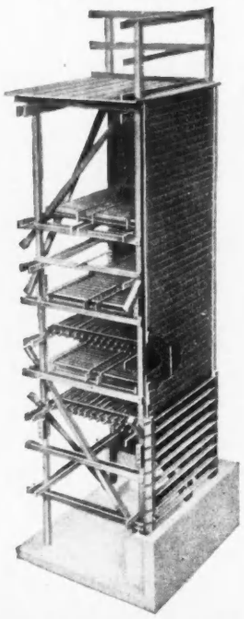

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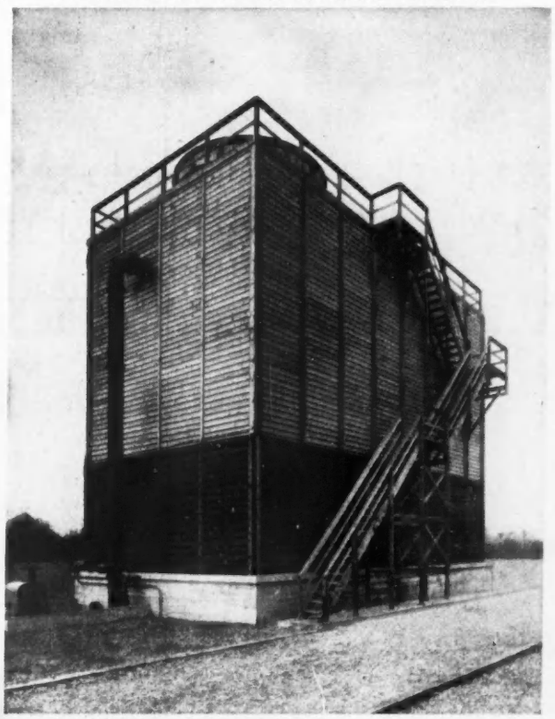

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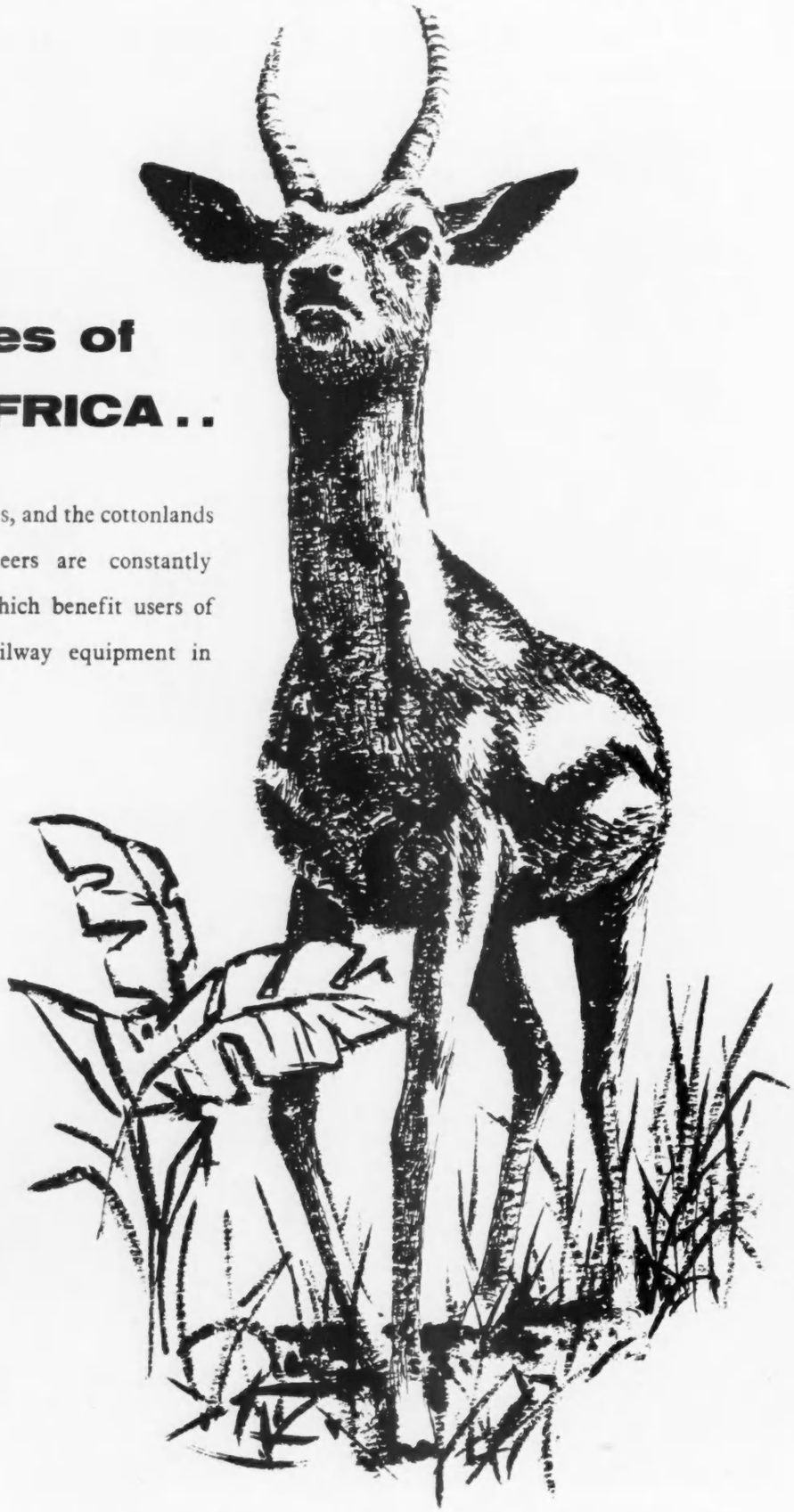

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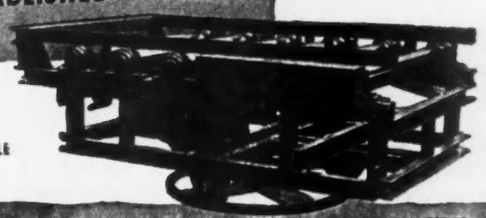

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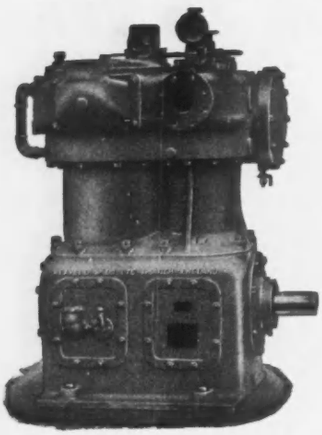

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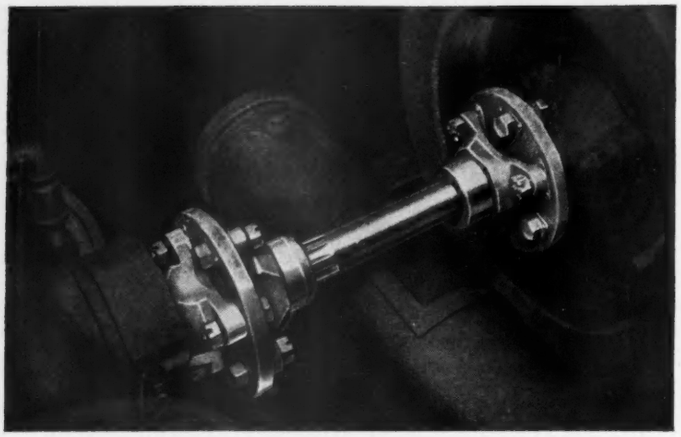

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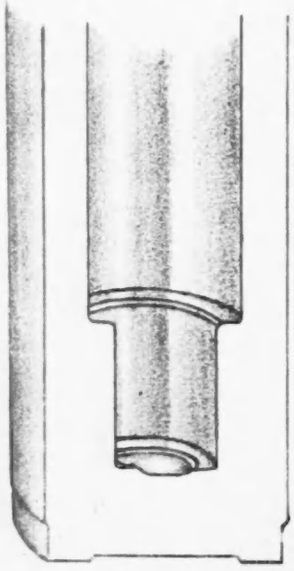

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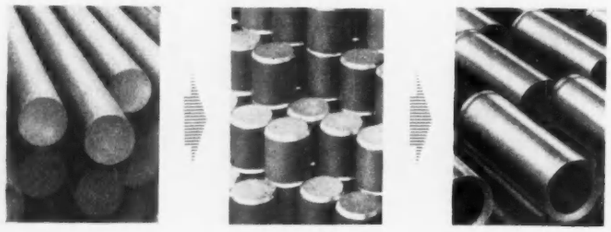

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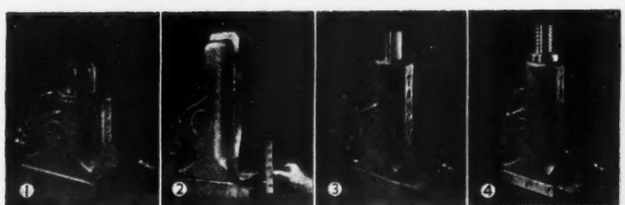

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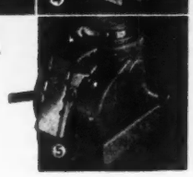
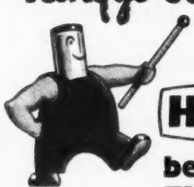


Tangye Jack



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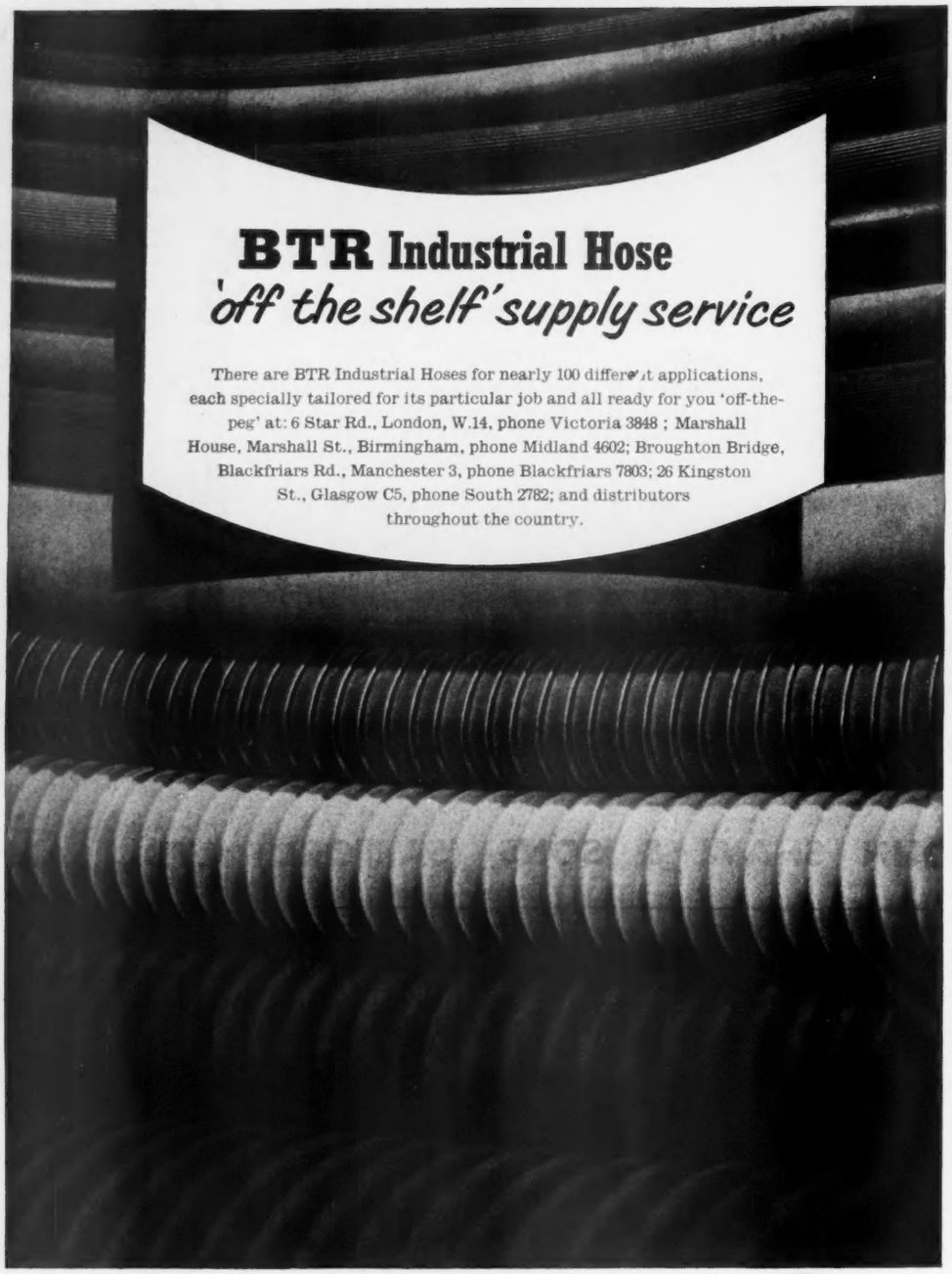

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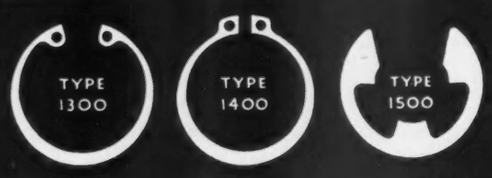

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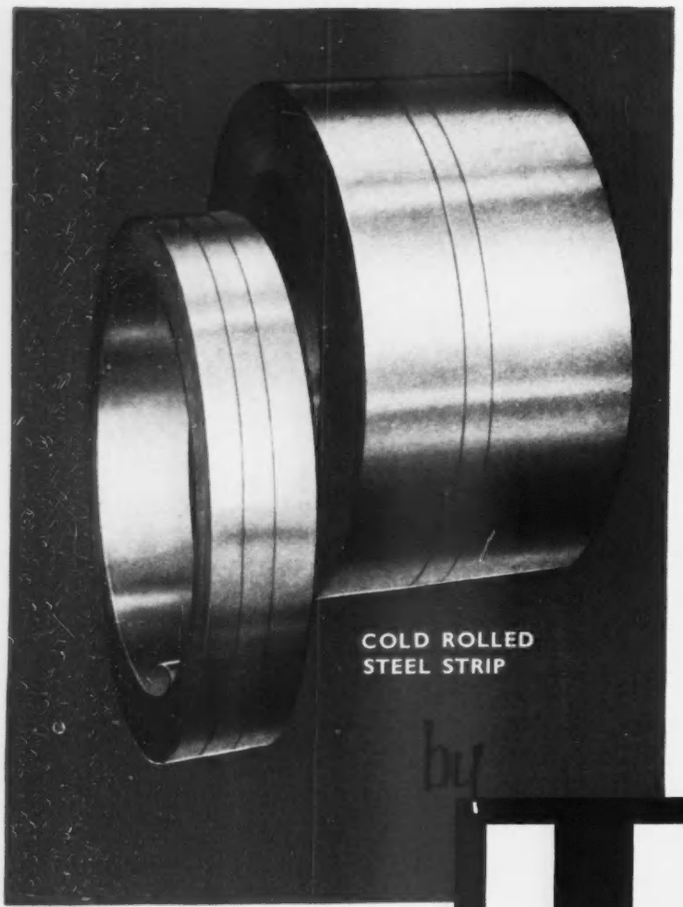

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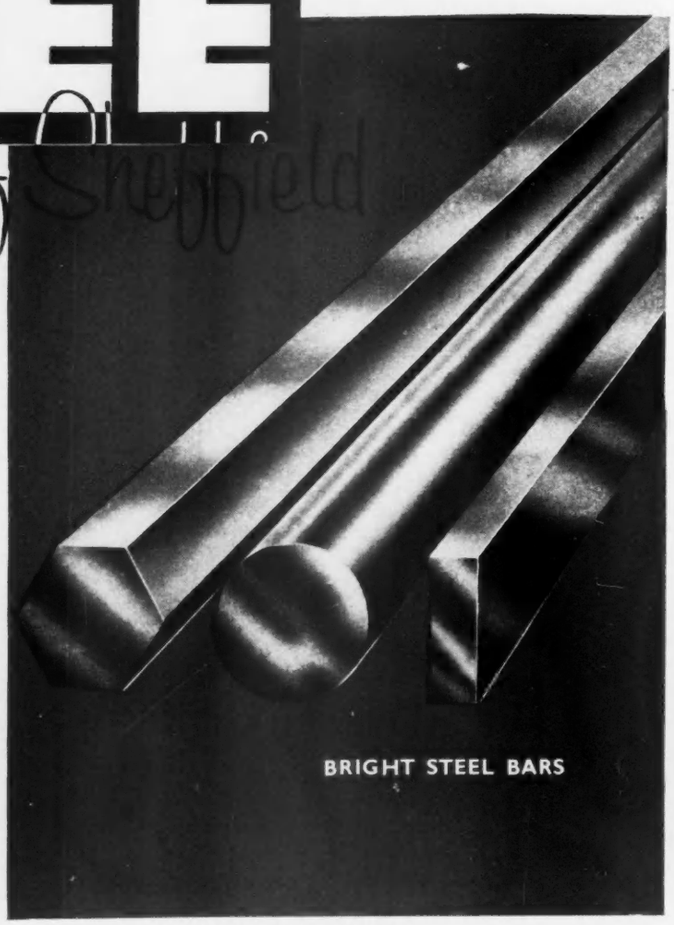

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Type 14 Low/Medium Pressure Hose. Sizes ⅛" to 2"
Cotton braided hose, lined and covered with synthetic rubber. For working pressures of 850 to 75 p.s.i., according to size.

Type 14WR Low-Pressure/High Vacuum Hose. Sizes 1¼" to 5"
This type is 'tailor made' to order. For working pressures of 200 to 100 p.s.i. according to size.

Types 75, 76, 77 and 78. High-Pressure Single Wire Braided Hose. Sizes ¼" to 2"
Choice of four different linings, to resist practically every oil, chemical, spirit or acid in ordinary industrial use. For working pressures from 4,500 to 500 p.s.i., according to size.

Type 99 High-Pressure Double Wire Braided Hose. Sizes ¼" to 2"
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These reusable end fittings are made of steel, cadmium plated. Some types also available in gun-metal or light alloy.

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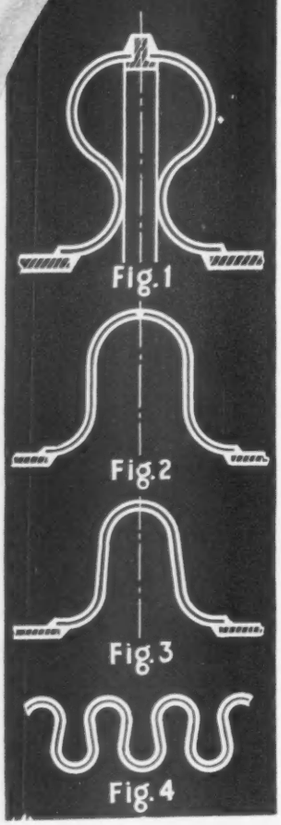
for PIPEWORK SYSTEMS



During the last fifty years Aiton & Co. Ltd. have designed and manufactured Expansion Fittings for both fluids and gases, either from carbon steels, ferritic alloy or stainless steels and in a variety of forms depending upon the working pressure and temperature, the degree of movement at terminal points and the thermal expansion of the piping system.

Fig. 1 Bellows expansion fitting formed by "S" pressings. Any multiple of bellows up to five in number can be supplied in sizes from 3 in. to 84 in. bore.

Fig. 2 An alternative bellows profile particularly suitable for transverse movement. The height of the bellows is varied to suit individual pressures and working conditions.

Fig. 3 A bellows profile which may be formed by deep pressing. This type of expansion fitting is built up in three or more sections with longitudinal welds.

Fig. 4 One of the profiles available for the Aiton "A" type expansion fitting. This unit is made by a special process which obviates the need for circumferential welding at the crown of, and between, convolutions.

Illustrated are an expansion unit 10 ft. in diameter fabricated as in Fig. 3, and a 10 in. internal diameter cargo oil line expansion fitting in stainless steel.

Further details of Aiton Expansion Fittings are contained in our illustrated brochures, copies of which will be sent on request.

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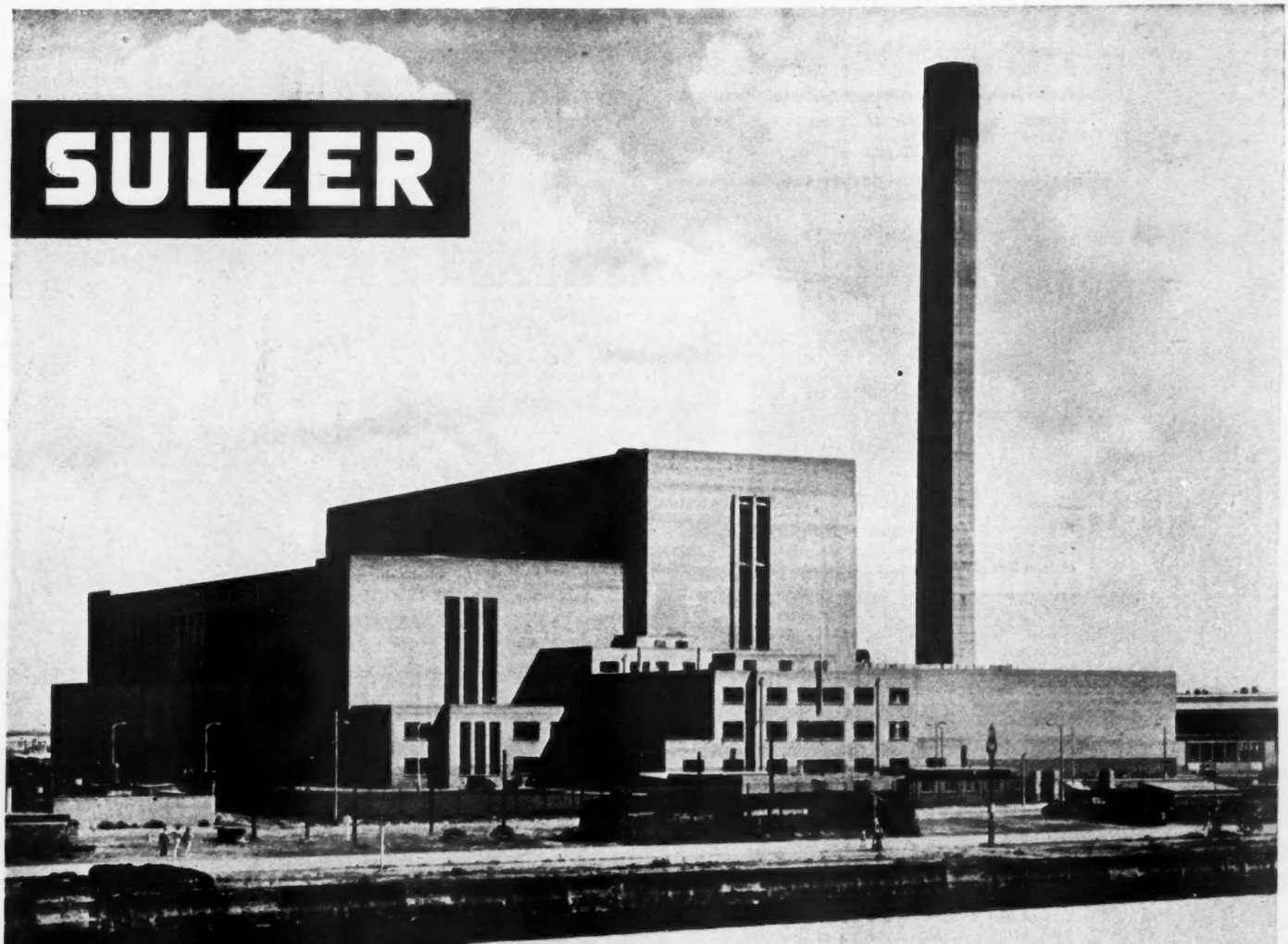

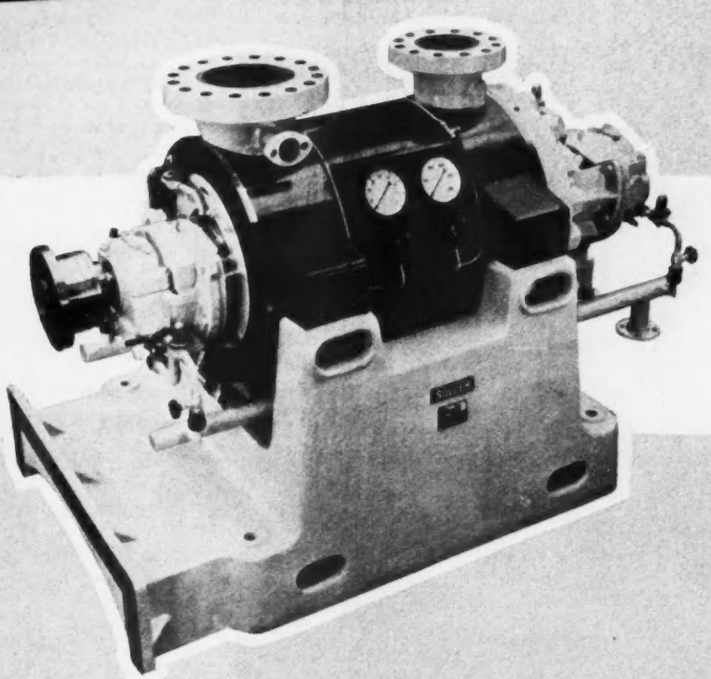

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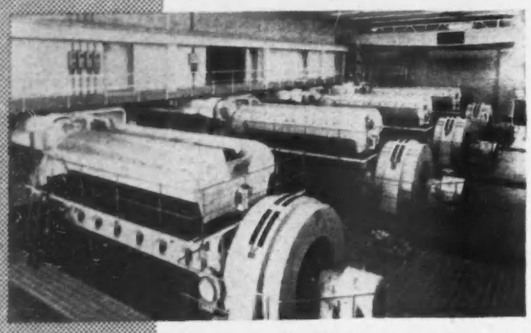

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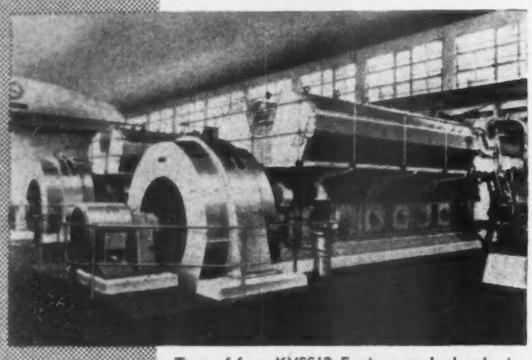

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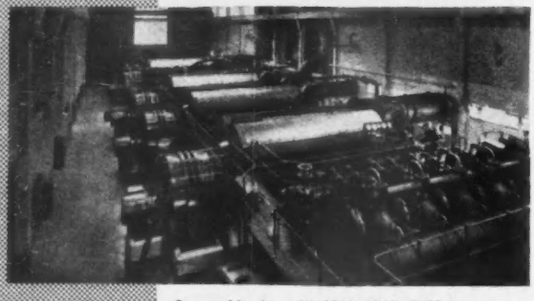
Six Mirrlees KVS12 Engines each developing 1777 B.H.P./1242 kW continuously on site at Lyallpur Power Station, Pakistan.



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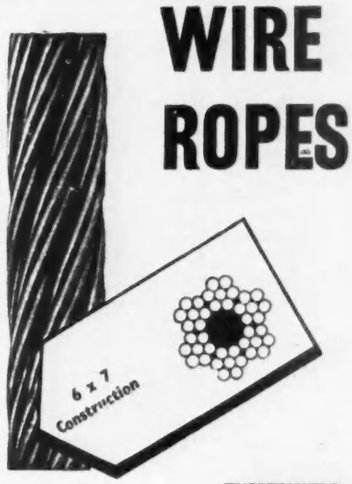

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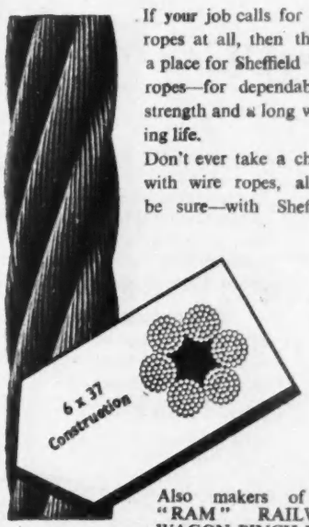

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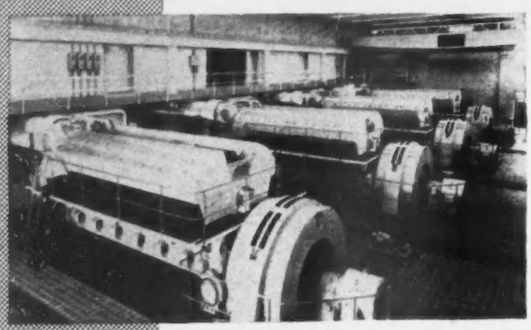

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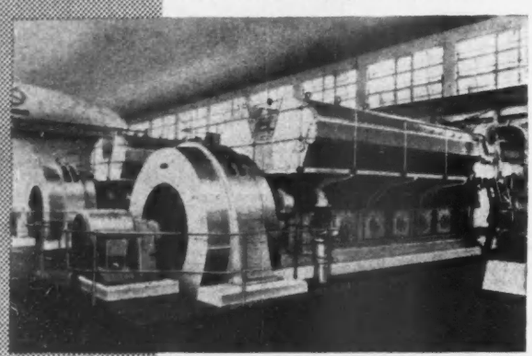

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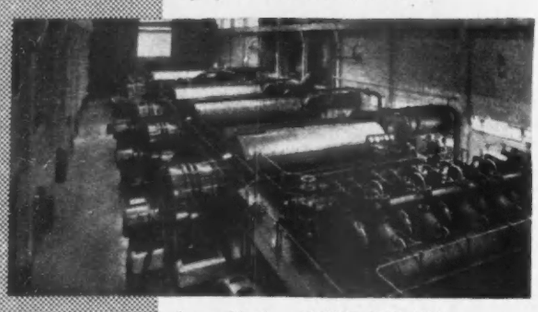

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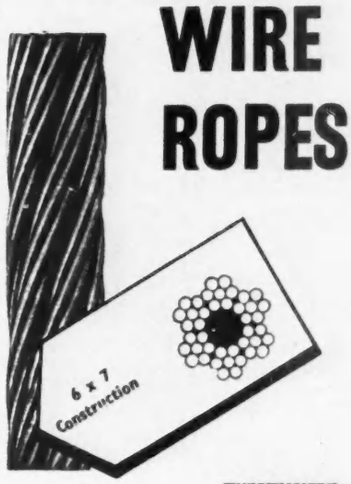

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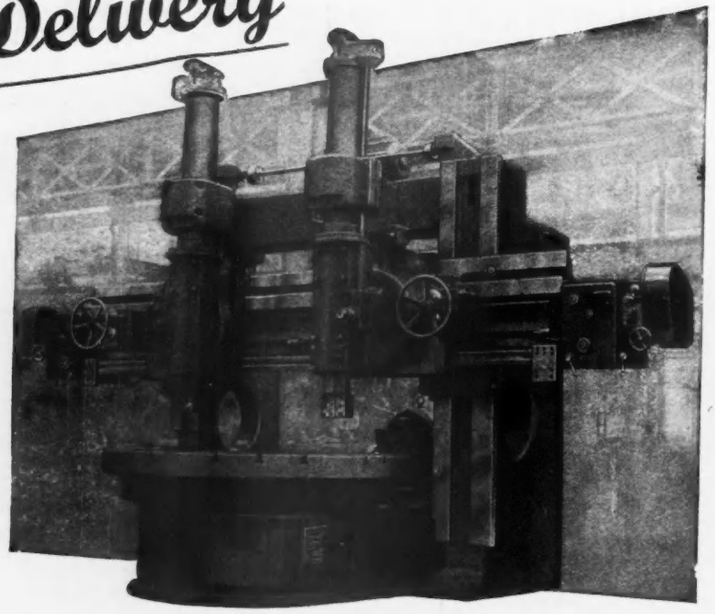

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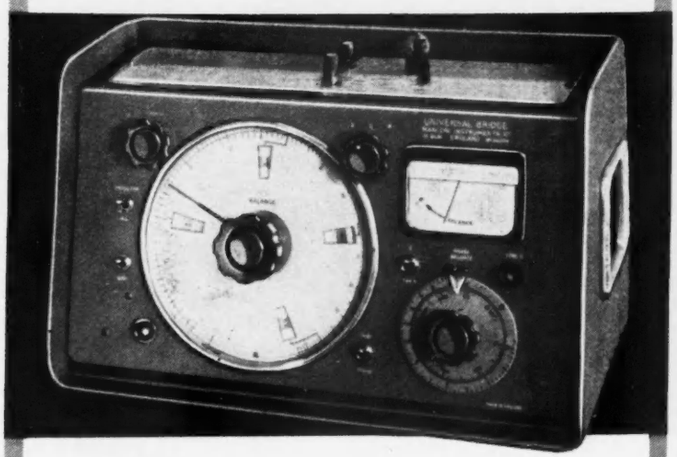

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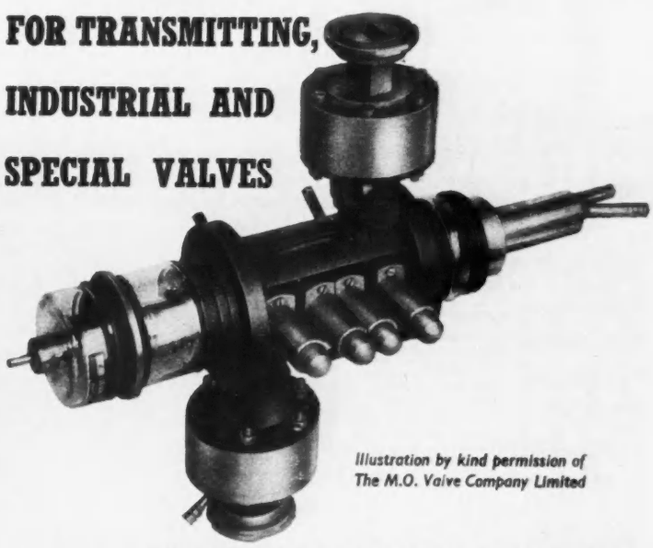

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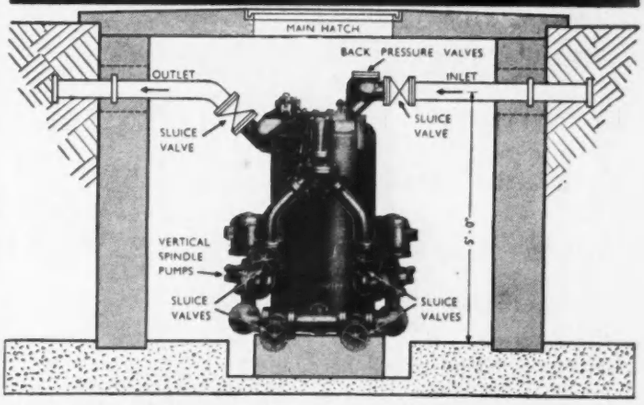

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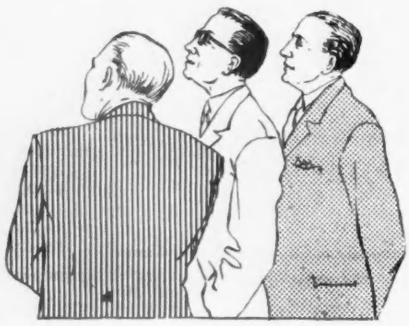

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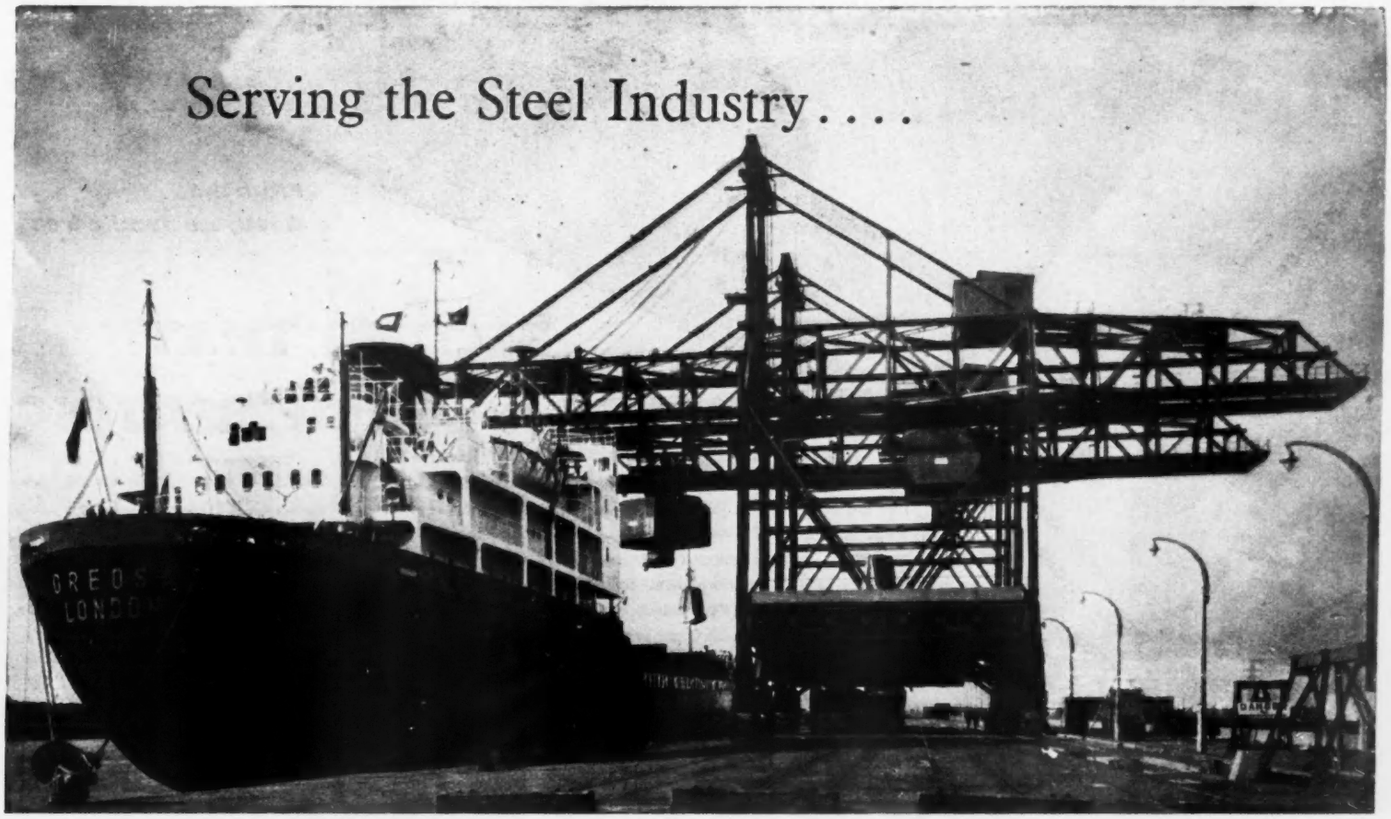

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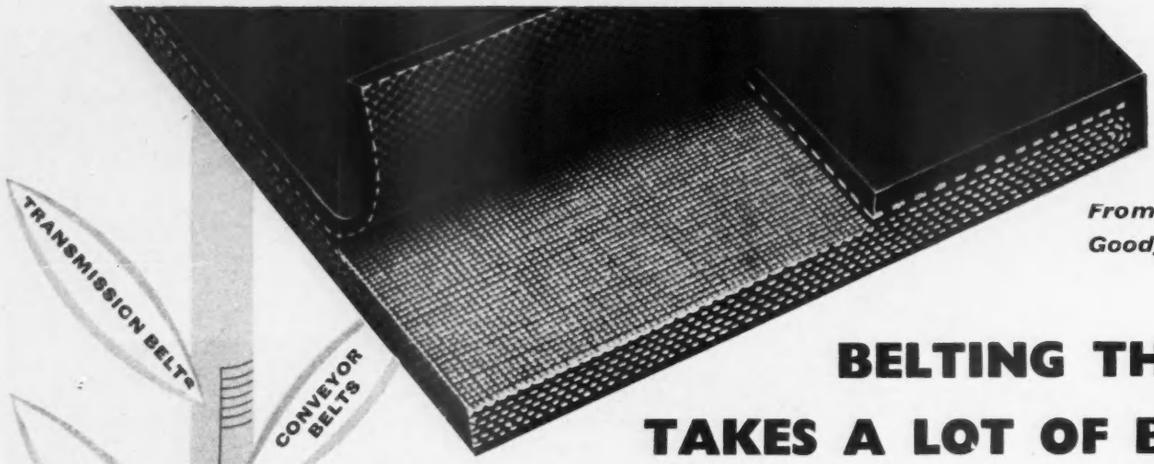

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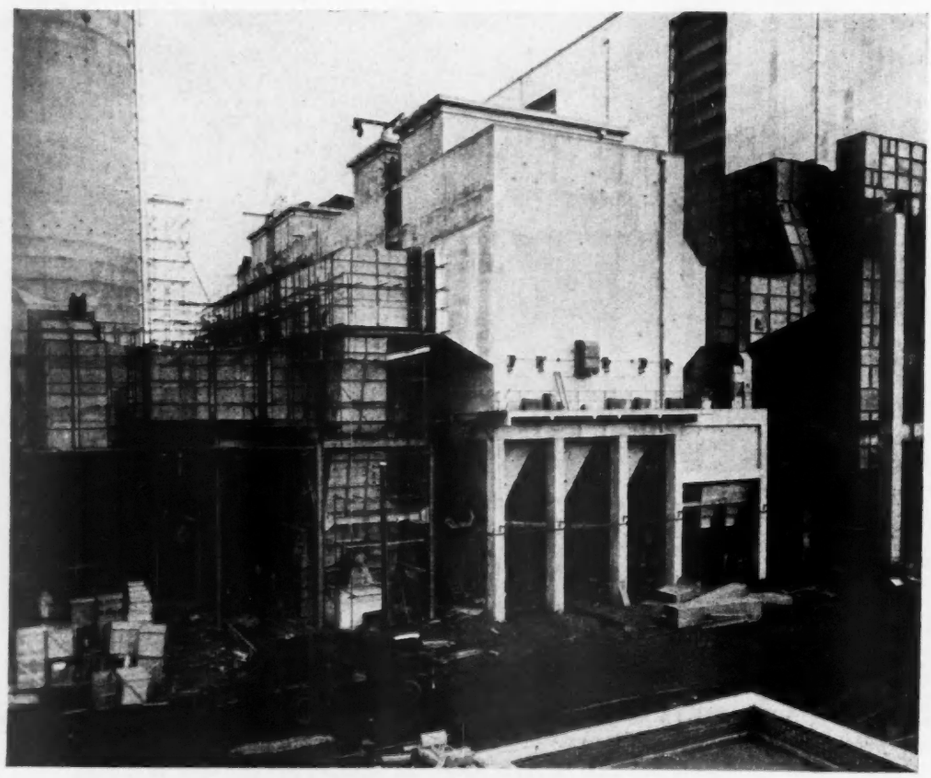

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THE ENGINEER

No. 5413 OCTOBER 23, 1959 VOL. 208

MOTOR-CARS ON SHOW

It may occur to few visitors to Earls Court that the fortieth annual exhibition of the Society of Motor Manufacturers and Traders was held last year in a country unexcelled in Europe for quantity of motor-cars produced. At that time there was debate as to whether this pre-eminence was justified by the merits of the products. But our moderate optimism upon the point has proved unjustified. Figures show that the United Kingdom was recently only the third largest producer in Europe ; and that despite an expansion in exports it was the largest exporter of cars to only three countries outside the Commonwealth—the United States of America, the Irish Republic, and the Sudan. In the two larger of these markets the British enjoy the advantage of being able to study the user's requirements and disseminate their own submissions without the possibly corrupting influence of an interpreter. Nor can this failure to compete so effectively elsewhere come as a surprise, for the manufacturers in this country seem to have done little satisfactory technical thinking, even if they have acted fast in designing new models and re-styling older ones, as was indeed essential if it was intended to continue to compete with foreign producers. A glance back over four years shows that a large investment of technical effort has been made without much apparent return. Attempts to make the synchromesh gearbox, inherently difficult to shift, compatible with two-pedal control entailed large diversions of design, development, production and sales activity on systems originating in England, Germany, and the United States, but have so far yielded little. This waste of effort appears at first sight the less justifiable when one reflects that the free wheel, now available only on foreign cars, would have solved all the problems that gave rise to such complications as mercury inertia switches. But few drivers, curiously and unfortunately, ever took a liking to a free-wheel, although certain makers persisted for many years in offering the device. Would it, we wonder, be welcomed on a car with two-pedal control and rapidly replaceable friction elements ? We cannot but doubt it ! It is, probably a consequence of this dissipation of effort, to some extent forced on transmission engineers in this country, that there has been widely adopted the Borg-Warner transmission which in the United States has in many cars been superseded by transmissions more highly adapted to the individual design. Engine design also has shown little sign of interesting development. We have seen one manufacturer discard an engine established in both single and twin overhead camshaft forms and introduce push-rod designs with bath-tub and hemispherical combustion chambers. Another maker has produced a V-8 on contemporary United States lines but, following the habits formed in making aircraft engines that are serviced from below, has placed the sparking plugs where they are accessible only by jacking the vehicle. This arrangement may not trouble the service station, upon which most drivers depend to-day. But we note that the ignition system is not fully screened or waterproofed ! The valve in-line push-rod design that is now a lowest denominator common to all the English car producers designing their own engines, save only the firms that regard racing as the proof of their products, has surely attained a nadir in a far from outstanding car in which the power unit weighs as much as the complete body shell.

A cherished ambition of the English manufacturer, we thought, is to produce a cheaper car, and the President of the S.M.M.T., last year, it will be recalled, saw a prospect of successes in this respect. He has been even more roughly refuted by events than have we. The minimum price of a factory-built car in England has gone up from about £230 to about £290 even before multiplication by purchase tax and the cost of retailing —which means a 25 per cent increase in the threshold of the market ! This trend to more expensive designs has deprived the exhibition of a British design, the old Ford " Popular," said to be suitable for under-developed countries, an abuse-resistant car with all the working parts enclosed and a body insensitive to abrasion—evocative, in fact, of a trials special with big wheels and brakes all round and a cabin added. But at the same time British manufacturers have not competed very effectively in the market for the more technically interesting cars. They continue to renounce the attractions of fuel injection for petrol engines, steplessly variable transmissions, and self-levelling or constant-rate suspensions. Although many users and buyers are eager that their cars shall look well, the makers offer neither the catalysed resin finishes popular on the Continent nor the long-lasting scratch-and-chip-resistant enamels favoured in North America. One visiting Earls Court this year for the first time might suspect that a fine summer had convinced the industry that it " ain't gonna rain" (or at least be foggy) " no more " : windscreens are fixed without semblance of apology and some of the latest models have such restricted side window openings that direct vision forward in fog is available only to the contortionist. But most drivers, we suspect, prefer warmth to vision, don't drive in fog unless they absolutely must, and even then tag on to someone else's tail ! So the manufacturers may be right. There is also to be discerned a trend towards electric windscreen wipers. We find it surprising because we doubt if there exists an English overload relay capable of protecting such a delicate device in freezing conditions. But then, of course, opinions differ as to the virtues of alternatives so that again manufacturers may be right.

All the above disappointments the more technical and enthusiastic motorist may feel are not wholly to be blamed upon requirements staffs apparently lacking any appreciation of what technology has to offer in the second half of the twentieth century. The buyer must take some of any blame there may be. The pity is that the British buyer has so little opportunity to appreciate what is being produced elsewhere than in Britain that

he is not a very satisfactory judge. In fact, engineers cannot draw much technical satisfaction from the exhibits, even though two or three interesting new cars such as the Triumph "Herald," the "Miniminor," a Daimler sports car and others have appeared this year. The largest native manufacturer has confessed, for example, inability to produce an air-cooled engine even equal, let alone superior, to those taken for granted in motorcycles and foreign cars. The stagnation in the power plant state of the art is the more regrettable when we recall that a corresponding state prevails among the smaller British aero engines, and that an engine of really high specific output and thoroughly refined design might well be able to follow the Volkswagen, Porsche, and 1172 Ford into use on aircraft. We note also that the tough task of building a true remote control for a four-speed gearbox on flexible mountings looks like being given up as too difficult.

In formulating their own requirements for their suppliers, the engineers show themselves little more demanding than their customers in the protected home market: we have seen small cars move up and large cars move down to 7in diameter headlamps, presumably to reduce costs. But the glass-envelope mechanically-aimed light unit such as the world's large-production cars use is neglected, and designers in this country tolerate axi-symmetric lenses even when their rate of manufacture is larger than that of some Continental firms which specify shapes to suit their bodies. The greater success of foreign designers of dynamotors also is conspicuous: to start an 800 c.c. twin with a compression of 9·2 without resort to the pendulum principle is a convincing demonstration of the abilities of this device, once used on some British cars, but given up, if we remember aright, in the 'thirties. Does it deserve revival? We would, more easily, return to our erstwhile optimism if it were a more regular routine to see a British motor engineer driving a product of other major motor manufacturing nations, with which he could compare his own. Perhaps, however, the major conclusion to be drawn is that while the home market remains protected so that buyers have not the knowledge to demand changes in design it seldom profits makers to put more advanced designs on the market. For they may meet sales resistance—especially if they seem more expensive—just because they are different; and be disliked by service stations for the same reason. Buyers, we fancy, are seldom conservative about styling, but often conservative about technical things.

REVISED PLAN FOR COAL

When the National Coal Board issued the general guide to its investment policy under the title of "Plan for Coal" nine years ago, there was every indication that there would be a rising demand for coal for a number of years. Until about two years ago, in fact, there even appeared to be evidence that the increases planned for coal production by 1965 would not fully satisfy the demand. The Board was widely criticised for lack of boldness in its planning. Towards the end of 1957, however, prospects of a considerable change in the situation became evident, when a slight industrial recession and a rapidly growing use of oil began to suggest that the continuous increase in coal production provided for in the overall plans was no longer necessary. Since that time, a continued decline in demand for coal has brought about, in Britain, as in other countries in Western Europe, an actual excess of productive capacity over coal requirements. No one can feel certain upon the point but it looks as though the decline may continue into the future.

To meet the changed conditions, the National Coal Board has made extensive revisions to its programme, details of which are given in a recently issued document, "Revised Plan for Coal." This publication, in addition to outlining the financial side of the plans, surveys the changes affecting the coal industry since the issue of the original "Plan for Coal" and the revisions included in the subsequent publication, "Investing in Coal," issued in 1956. It is shown that, based upon 1955 prices, a saving of £175,000,000 will be made on the originally estimated capital expenditure for the period 1956–65, and that over the next six years £440,000,000 is to be spent. This expenditure will be devoted to 168 major colliery development schemes, about ninety new schemes, and in carrying out minor improvement works at collieries. Fuller details are given of the previously announced scheme for closing some 240 uneconomic collieries and reducing manpower by up to 11 per cent. A big cut is to be made in opencast working (rather than close collieries producing an equivalent amount of coal), despite the relative cheapness of this form of working. A welcome degree of flexibility is provided in the plan by a decision to close not fewer than thirty-five or more than seventy uneconomic pits, according to the demand which will exist in 1965. For, until the existing industrial recession ends, no one can feel sure how the situation will develop, though a steadily increasing demand, such as was foreshadowed for 1959, seems unlikely now. It is expected that the plan will result in an annual coal production of between 200 and 215 million tons in 1965, with a productivity of 30 cwt to 31 cwt per man shift, as compared with 25·3 cwt last year. Practically the whole of the proposed output will come from about 550 collieries—200 less than at present.

When the original plans of the National Coal Board were announced in 1950, it was emphasised that the programme was flexible and would have to be revised from time to time in the light of current trends. At that time, and indeed up to two years ago, few could have forecast that replanning would be necessary to conform with a declining, instead of an increasing, demand. In this connection the overall plan for the production of coal from a smaller number of more highly efficient mines by about 1965 is to be commended. It is stated in a summary to the plan that "the governing factor will be the level of demand for coal and the extent to which the challenge from oil can be met." This competition with oil will obviously be an essential factor by which the outcome of the replanning will be judged a success or not, but two points made in the report give rise to some doubt that every possible measure is to be taken. First, opencast mining, which at present provides the most economic means of coal-getting, is to be almost completely terminated—surely to compete in price with oil, the cheapest means of coal production are essential! But no doubt that decision has been taken for reasons other than the economic. Secondly, the Board states that its main object is to hold the price of coal steady—instead, one would imagine that the primary aim should be to reduce prices. Meanwhile, there are vast stocks of coal stored at a high cost in this country. They cannot be improving in condition and it does not appear very likely at present prices that the amount will be appreciably reduced for many years to come. In the circumstances, we wonder what it is that deters the Board from offering some of this stock to the market at a price competitive with oil. The effect might be to arrest the decline in the demand of existing markets which might then be retained during the time it will take to bring the plan to fruition. Even were no such consequence foreseeable, the Board must surely

wish to be rid of an embarrassingly large investment in stocks of coal. But to be effective in reducing stocks, a price reduction would have to attract new buyers (or bring back old ones). Perhaps the Board's assessment is that since the market would perceive the temporary nature of any reduction, no new buyers would come in, the consequent effect being merely to reduce the Board's income ! If so, then willy-nilly the Board will have to carry its large investment in stocks far into the future.

BUSY TIME FOR I.MECH.E. PRESIDENT

In the middle of last week Mr. Desmond Carter, President of the Institution of Mechanical Engineers, had a busy time. On Wednesday night, October 14, he presented his Presidential Address to the members and followed that up by presiding over an informal Council Dinner at St. Ermins Hotel, Westminster ; and on the following night he presided over the full-dress Annual Dinner of the Institution at the Dorchester Hotel. Incidentally, the Institution is holding all main meetings this year on Wednesdays instead of Fridays as it used to do. But the large size of the President's audience for his Address was due, we fancy, much less to that change than to his own popularity with the members.

In his Address the President brought the whole Universe under review, from the immensity of the galaxies to the minutiae of mesons and electrons. He pinned down the diesel in the very middle of this tremendous canvas and put the gas turbine in quite another place ! All present enjoyed it. Elsewhere in this issue we print parts of the Address, primarily those parts concerned with engineering technicalities. We are sure readers will be interested. But we fear that we shall not in any real way have conveyed to them the true flavour of the Address. For Mr. Carter kept going off into discussions of matters not strictly relevant to technicalities, but yet intensely relevant to the life and work of an engineer and a designer. Humour, too, kept peeping through to prevent these philosophical discussions of life from becoming too intensely serious. By contrast, the speeches at the Dinner of the Institution on the following night fell, we felt, rather flat, though Viscount Simon, in proposing the Toast of the Institution, had some sensible things to say about the disappearance of the lead in technical things which this country secured 100 years ago and about the quality of Russian engineers and the probability that they would be competing for orders in world markets within ten or fifteen years or so. Unfortunately, there appears to be growing up in all the major institutions a convention that the President, in replying to the Toast of the Institution, must refer to certain (rather dull) Institution activities, and that whoever proposes the Toast of the Guests must mention a number of names. Neither convention is conducive to the making of an attractive after-dinner speech, however much they may please the Secretary !

ATMOSPHERIC POLLUTION

The amount of attention which is now being directed towards the problem of atmospheric pollution and its prevention in large cities and industrial areas in all parts of the world is shown by the fact that nearly two hundred delegates from twenty-nine countries attended the International Conference on Clean Air, held at Seymour Hall, London, from October 20 to October 23. This conference, which is the first international gathering of its kind, is also being attended by about a thousand delegates from the United Kingdom. It has been organised by the National Society for Clean Air—which originated in 1899 as the Coal Smoke Abatement Society—to celebrate the Diamond Jubilee of the Society. No less than fifty of the seventy-five written contributions presented for discussion have been received from overseas countries and they cover a comprehensive range of subjects. Together with papers on the need for and promotion of closer international co-operation, there have been discussed national air pollution problems, legislation and administration in this and other countries. The discussions on these subjects, and the sessions dealing with technical problems in preventing pollution, its investigation and measurement, and medical and other research in progress provided all delegates with a valuable fund of information and possibly lead to new approaches to a subject which is of vital importance to all communities. Attention is also being directed to the growing problem of fumes from road vehicles.

The value of this conference will undoubtedly be enhanced by its international aspect. It is providing delegates with an excellent opportunity to discuss their individual problems and the progress which has been made in technical methods or by legislation in different parts of the world. Concurrently with the conference there is being held a Clean Air Exhibition in which about thirty institutions, public bodies and firms from this country are displaying equipment for detecting and preventing atmospheric pollution. This exhibition has been open daily from 9 a.m. to 6 p.m. and admission to it is free. It is to be hoped that the exhibition is receiving the careful attention it deserves from all industrial concerns making and using the appliances and plant responsible for much of the present air pollution.

The Engineer—100 Years Ago (OCTOBER 21, 1859)

"The Future of Civil Engineering"

"It may be safely concluded that the profession of civil engineering has attained the larger share of its present influence and importance in the development of the railway system. . . . Engineering, whether it be considered as a science or an art, is in its nature more progressive than almost any other entering into the common pursuits of life. As practised within the last thirty years, it has been frequently unsuccessful, so far as pecuniary results have been concerned. It is impossible to deny that grave errors have been committed when so many millions of capital are known to have been hopelessly sunk, and whilst the advantages sought to be obtained are as yet only partially enjoyed by the mass of our population. It is not enough to compare our railway system with the old dispensation of stage coaches. Whatever result may be disclosed, the comparison is incomplete until the former has been brought, as the latter is believed to have been, to the highest possible excellence.

"There is every reason to believe that our railways are now very much farther from absolute perfection than were our mail coaches, considered simply as such. We are not to expect, therefore, the perpetuation of the present standards of engineering skill. They will be essentially modified, and on the whole very much advanced. The results of the engineering of the first half of the present century are—some in the order of nature, some alas ! too soon—becoming better understood, and are leading to comparisons and further inquiry. The engineers of the old school are passing away. Some of the greatest names in the profession—names which for many years have been constantly associated with the material progress of the world—and which have been spoken everywhere in familiar reference to the greatest works of modern times, have become historical. However posterity may pronounce upon the practice of these engineers, the great influence which they exerted in the advancement of engineering will be acknowledged. Nor shall we do any injustice to their memory in endeavouring to improve upon their practice."

Nuclear Reactors for Marine Propulsion

(*Concluded from page* 426, *October* 16)

No. VI—ORGANIC MODERATED REACTOR FOR A DRY CARGO LINER

To conclude this series of articles we reproduce extracts from a paper " The Prospect for a Nuclear-Powered Dry Cargo Liner with Particular Reference to the Organic Moderated Reactor," presented by E. C. B. Corbett and E. P. Hawthorne at the Institution of Naval Architects on October 7. This paper outlines a design study of a nuclear-powered ship derived from the " Mariner " class hull to carry refrigerated foodstuffs from Australia to the United Kingdom. The economic aspects of this design were summarised in an article on page 438 *of last week's issue. In the following extracts from the paper we concentrate on the reactor and propulsion machinery.*

FOR the purposes of this paper attention was concentrated on the organic moderated reactor, but many points are brought out applicable to all systems, so that the conclusions may be of wider interest. A family of conventional and nuclear cargo ships has been derived from the " Mariner " class and one of them, a nuclear-powered ship designated " N2B, " is considered here.

Accommodation has been worked out approximately and the arrangement envisages the engine-room in a conventional position with the reactor room forward of the engine-room. Over the reactor room is the reactor refuelling compartment with its ancillary equipment. The containment vessel is designed to accept a pressure of 105 lb per square inch which offers an acceptable margin over the potential pressure likely to arise as a consequence of failure of the primary circuit. In addition, the containment vessel has integral shielding consisting of 3in thick lead slabs bolted to the casing, this being provided to reduce the radiation levels outside the containment vessel in the event of a release of radioactivity inside the containment vessel. The ship outside the reactor room itself may thus be treated as a normal ship design problem. The table gives the leading particulars of the ship.

Particulars of Nuclear Ship " N2B "

Speed, knots	19·8
Draught, maximum,	32ft 9in
Displacement, maximum, tons	25,710
Block coefficient	0·619
Shaft horsepower (propulsion only)	19,450
Reactor heat output, MW (continuous)	58·2
Lightship	12,410
Deadweight, refrigerated ship, tons	13,300
Deadweight, cargo, tons	12,640
Total capacity, cubic feet	872,000
Refrigerated capacity, cubic feet	468,000
Fuel oil, tons	250
Average terphenyl consumption on a round voyage, tons per day	0·34
Terphenyl polymer stowage capacity, tons	60
Terphenyl stowage capacity, tons	60
Reactor cost, £	820,000
Total cost, £	3,974,000

Schedule of Weights of Reactor and Associated Plant

Reactor : complete with control rods and gear, fuel and cans, fuel handling gear, tons	85
Moderator and coolant (reactor and circuits), tons	50
Primary circuits : including main pumps, pipe work and valves, heat exchangers, steam drums, tons	90
Shielding :	
Primary with structure, tons	790
Secondary, tons	660
Containment, tons	160
Auxiliary circuits : including emergency cooler, drain tanks, polymer storage, chemical plant, nitrogen supply and trace heating, tons	45
Total, tons	1880

Propulsion Machinery

The propulsion of the ship is by conventional steam turbines modified slightly to suit the preferred steam cycle. The maximum steam temperature available from the reactor at full load is 620 deg. Fah. Several possible steam cycles have been examined, involving water extraction, separately oil-fired superheating and various means of reheating. The preferred cycle involves water separation between the high-pressure and low-pressure cylinders by a fixed blade cyclone separator. This cycle shows to particular economic advantage and involves the least complication relative to the basic straight expansion cycle. A steam pressure of 630 lb per square inch gauge at superheater outlet has been selected, as lying close to the optimum.

The main engine is a two-cylinder cross compound set, with an impulse high-pressure turbine and single flow impulse-reaction low-pressure turbine, coupled to a double reduction gearbox. The steam at exit from the high-pressure turbine is estimated to be 7·7 per cent wet : it is dried in the steam separator to 1 per cent wetness before entering the low-pressure cylinder. The exhaust wetness from the low-pressure turbine is 11·3 per cent at 28·5in Hg.

The turbine is designed to give a service shaft horsepower of 19,450 and to accept a 10 per cent overload ; the extra steam required for the overload condition being arranged to enter the turbine via a group of first stage nozzles in the high-pressure turbine. An astern turbine is incorporated in the low-pressure turbine casing. At the continuous rated power the steam requirements for the turbines on a non-extraction rate is estimated at 149,000 lb per hour, and included in this figure is an inherent extraction from the steam separator, heat from which is regained in the de-aerator. The total continuous steam demand from the reactor is estimated at 196,910 lb per hour.

The final feed temperature for this cycle should from thermodynamic considerations lie in the range 320 deg. to 340 deg. Fah. Also, from practical considerations, it should be maintained above 280 deg. Fah. to prevent solidification of the primary terphenyl coolant in the evaporators. A final feed temperature of 320 deg. Fah. is satisfactorily achieved by bled steam from the high-pressure cylinder at 121 lb per square inch absolute.

There is always a possibility when manœuvring or in port with very light loads that steam production will exceed demands and a single pass dump condenser is arranged to receive the surplus steam. The dumping arrangements are automatic, being controlled by safety valves set at a lower pressure than the normal safety valves to atmosphere and, to avoid additional priming capacity, the circulating water is arranged to flow first through to the main condenser and then via the dump condenser overboard. Suitable by-pass arrangements are fitted so that the dump condenser can be in use when the main condenser is being serviced.

To supply steam for de-aeration of feed-water various pumps are driven by back-pressure turbines which exhaust at 30 lb per square inch absolute to a common auxiliary exhaust range. Steam from this range is used for the main de-aerator steam requirements, for the evaporator and for various ship services. To maintain a dry exhaust range in the back-pressure turbo-pumps, and to limit wetness in the exhaust of the auxiliary turbo-alternators, these are supplied with high-pressure steam throttled to 250 lb per square inch gauge.

When manœuvring or in port any surplus steam from these pumps is led to the dump condenser ; the final feed temperature is then maintained above 280 deg. Fah. by throttled high-pressure steam to the high-pressure heater.

The feed system is enclosed and arranged so that condensation from all auxiliary causes is delivered to the main feed service tank and via a de-aerator and high-pressure feed heaters to the heat exchangers at a temperature of 320 deg. Fah. To maintain purity of the feed-water low-pressure and high-pressure filters are arranged, and for record purposes salinity indicators are fitted at the outlets of the various condensate systems. The make-up feed-water is passed through a mixed bed de-ionisation unit before entering the main condenser. This treatment of the feed-water is considered to reduce greatly the necessary maintenance of the main heat exchangers due to a reduction in the deposits and corrosion rate, and will have a beneficial effect on the operating life of the steam plant generally.

All pumps in the engine-room are duplicated and the essential equipment for the ship's services supplying and controlling the reactor are arranged above waterline level and inboard of the collision protection.

For initial starting of the plant a light-weight high performance water-tube boiler is fitted and is of such a capacity that normal ship's services can be maintained while the main turbines are developing 20 per cent of their normal rated power. In the event of a reactor total failure, the ship will not be incapacitated. The boiler should burn low viscosity fuel oil so that bunker tank heating is unnecessary.

For normal ship's services three 600kW turbo-alternators are fitted, each being independent and complete with condenser, vacuum augmenters, circulating pumps and extraction pumps, and operating on steam at 250 lb per square inch gauge at 562 deg. Fah. One generator will take the full sea load, excluding the refrigerating machinery, while two units will be needed for the normal ship's load, refrigerating machinery, and cargo winch load. Normally, the primary coolant circulating pumps would be supplied by a 450kW turbo-alternator set. In the event of failure of this alternator an automatically started 450kW diesel alternator set is arranged to come into operation within ten seconds of a power failure. In addition, the pumps can be supplied from the main 600kW alternators.

Reactor Room

The reactor room, 45ft long and 45ft wide, is immediately forward of the engine-room and contains the complete nuclear steam-raising plant and all plant associated with the reactor. The containment envelope shown in Fig. 1 is a vertical cylinder, 38ft diameter and 38ft high (with semi-ellipsoidal ends), fabricated from 1¼in thick mild steel plate. The vessel is fixed at its lower end to the main shield structure and at its upper end in the region of the fuel-handling trunk, which is an extension of the containment, by means of radial keys permitting vertical and radial movement. The total weight of

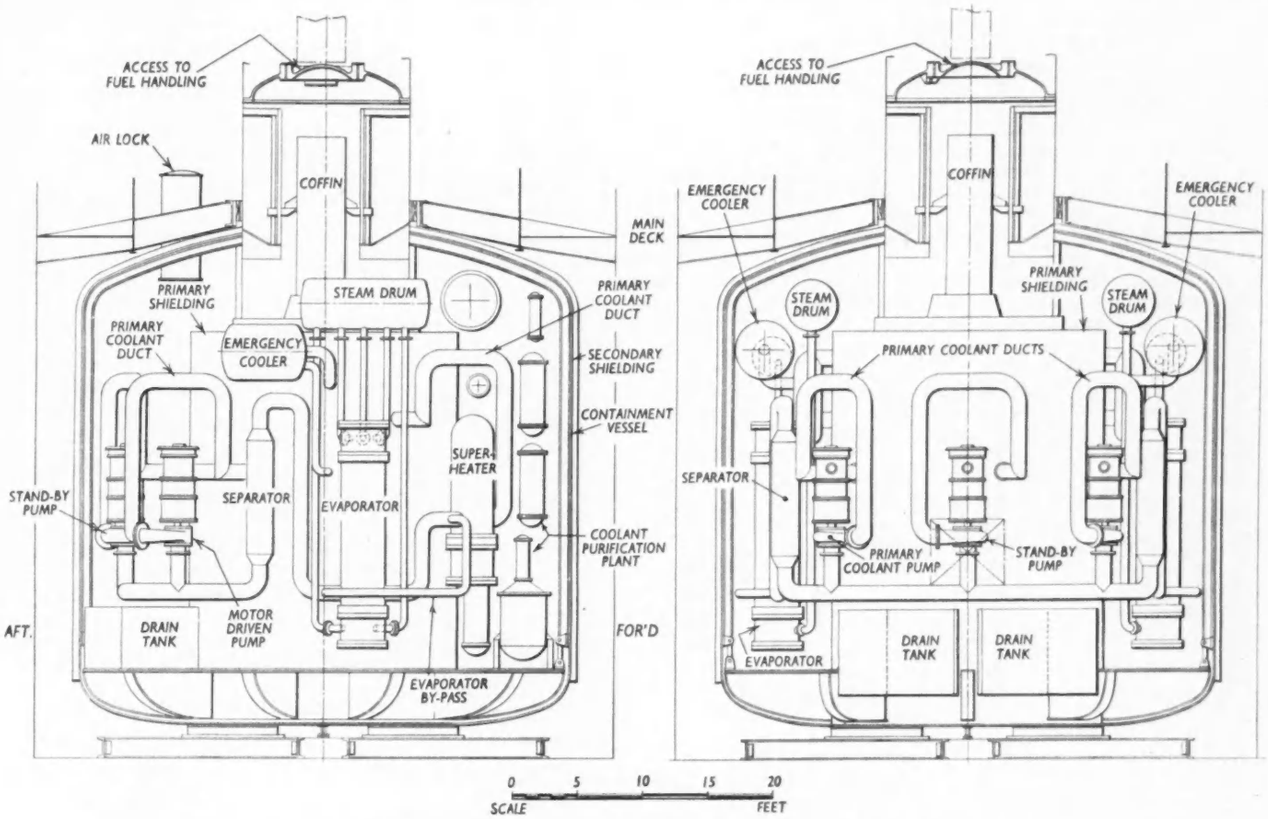


Fig. 1—Machinery arrangement, reactor room longitudinal and transverse elevations

the containment and its contents is carried through the main shield structure to a series of radial girders which distribute the load to the ship's double bottom structure and are arranged to allow differential movement. The secondary shielding is carried on the outside of the containment vessel and adds a considerable load at the junction of the vessel and the main shielding structure. To assist in bearing this load ties are arranged at circumferential intervals inside the containment skin to distribute the load to cantilever beams extending from the main shield structure. These cantilever beams are not attached in any way to the containment vessel wall.

The reactor core (Fig. 2), 5ft 9in diameter and 5ft high, is cooled and moderated by terphenyl with associated polymer and is mounted in a mild steel cylindrical pressure vessel, 9ft 9in diameter with a wall thickness of $\frac{3}{4}$in. The terphenyl, at a maximum pressure of 90 lb per square inch gauge, enters the reactor vessel above the core, flows down the annulus surrounding the core, then upwards through the fuel and moderator channels, and leaves by ducts at the upper end of the reactor vessel. Connections are in the upper part of the pressure vessel to ensure that the core remains submerged in terphenyl under accident conditions.

The fuel elements proposed are uranium oxide, clad in stainless steel, in the form of bundles of nineteen unfinned circular rods (Fig. 3). The bundles are divided longitudinally into two parts in order to allow axial cycling of the fuel.

The reactor is controlled in the conventional manner by the insertion of boron steel rods into the core. The closeness of the lattice pitching in this type of reactor implies that to meet the requirement of fuel withdrawal at any time, the fuel-handling equipment needs unrestricted movement above the core. The control rods are therefore inserted from below the core, and fit into channels similar to the fuel element channels. Each control rod is powered by an electric motor mounted above the core outside the pressure vessel. The drive is transmitted through an electrodynamic coupling to a vertical push rod running outside the reflector and having its lower end connected by a beam structure to the bottom of the control rod. Electrical or motor failures or scram conditions de-energise the couplings, and a long spring inserts the rods into the core, since it is considered that in any marine reactor the control and safety rods should always be positively inserted into the core.

The control rods are divided into three groups, fine, coarse, and safety. The fine rods provide regulation for minor load changes. The coarse rods back up the fine rods for major load changes, and balance out the reactivity variations caused by xenon and samarium poisoning, core burn-up and fuel rearrangements after refuelling. The safety rods are sufficiently effective to shut down the reactor indefinitely under all conditions.

There are two completely separate main heat exchange circuits arranged in parallel, each comprising separate superheater and evaporator sections of shell and tube construction with the terphenyl on the shell side, a steam separator to deal with small heat exchanger leaks, and an electrically driven centrifugal circulating pump. A standby terphenyl pump can be connected to either heat exchange circuit in the event of the normal pumps failing. The steam side of the heat exchange circuits follows the normal pattern of natural circulation systems.

The primary coolant pressure at the top of the reactor is maintained constant at 75 lb per square inch gauge by means of nitrogen pressure communicated to the fluid in a pressurising tank. Normal changes of coolant volume are accommodated by displacement of gas in the pressurising tank. Some nitrogen dissolves in the coolant and becomes irradiated before being extracted by the gas removal plant. For this reason low argon content nitrogen obtained by liquefaction of air should be used, thus ensuring that effluent gases are of low radioactivity.

Since the organic is solid at normal ambient temperatures provision must be made for heating the equipment containing it when necessary. Electrical trace heating is considered to be most appropriate, since it can be conveniently applied to systems with a number of individual items of plant. Pipes and ducts may be heated either by low-frequency induction coils on the outside of the lagging or by means of electrical resistance heaters on the metal surface, and tanks may be fitted with immersion heaters. For this ship normal trace heating requirements will be 75kW during start-up or prolonged shut-down and approximately 30kW while the reactor is in operation.

The containment atmosphere will be conditioned to a temperature of around 80 deg. Fah. by blowing it over cold brine coils inside the containment. The cooling duty of 25,000 B.Th.U. per hour will be carried by a refrigeration plant outside the containment and will be fairly constant whether the reactor is on load or not.

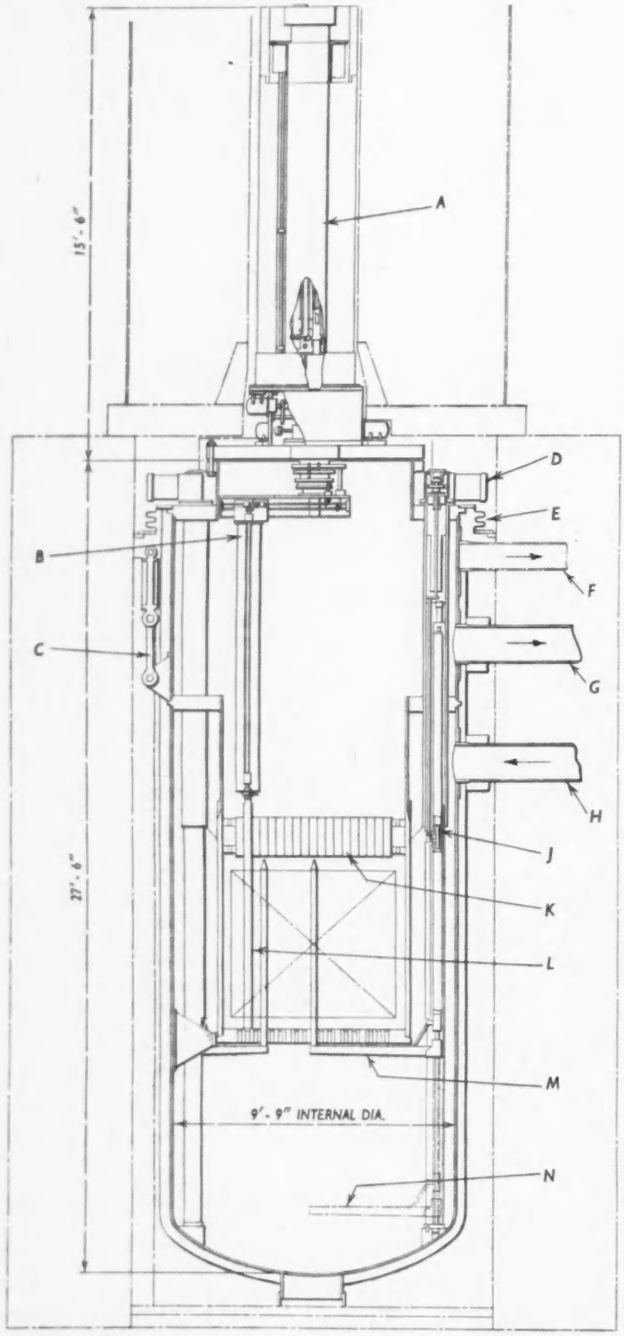
When the reactor is shut down, heat is still produced in the core due to the decay of fission products. This heat is normally removed by the main heat exchange systems, but duplicate emergency cooling circuits are provided, one port and one starboard. These operate by natural convection and dissipate the heat to the atmosphere. They are thus independent of power supply and will operate with the ship stranded and lying at extreme angles of heel.

Due to slow breakdown under irradiation,

the organic coolant must be processed to remove damage products, and fresh terphenyl added to maintain an equilibrium composition. The damage products are mainly polymer and hydrogen, with some methane, all dissolved in the coolant. These are removed by by-passing some of the coolant from the main circuit, filtering to remove particulate matter, degassing by flashing in a low-pressure tank and finally distilling. The purified terphenyl from the still and the make-up terphenyl are returned to the main circuit, while the polymer is removed for storage and disposal. This processing plant is compact and straightforward, and should prove very reliable. It can also be used to remove fission products from the coolant in the event of fuel element can failure.

The primary core shield is of composite design and is made up of steel, lead, and water layers. This shield, combined with the low primary circuit activity, gives sufficiently low radioactivity inside the containment to permit refuelling and maintenance working without undue restriction. Secondary shielding is provided on the containment envelope to allow access to the reactor room in the event of accidental fission product release into the containment.

The reactor incorporates a fuelling machine which can remove or replace any fuel element in the core, discharging through an opening in the reactor vessel head into "coffins" which can be handled by dockside cranes.



A—Charge-discharge machine and coffin.
B—Fuelling arm.
C—Reactor support links.
D—Control rod drive motor.
E—Sealing bellows.
F—To emergency coolers.
G—Primary coolant outlets.
H—Primary coolant inlets.
J—Control rod operating mechanism.
K—Fuel element support grid.
L—Fuel element.
M—Control rod actuating arm in fully raised position, with rod in core.
N—Control rod actuating arm in position when control rod is fully withdrawn from core.

Fig. 2—Reactor—vertical cross-section

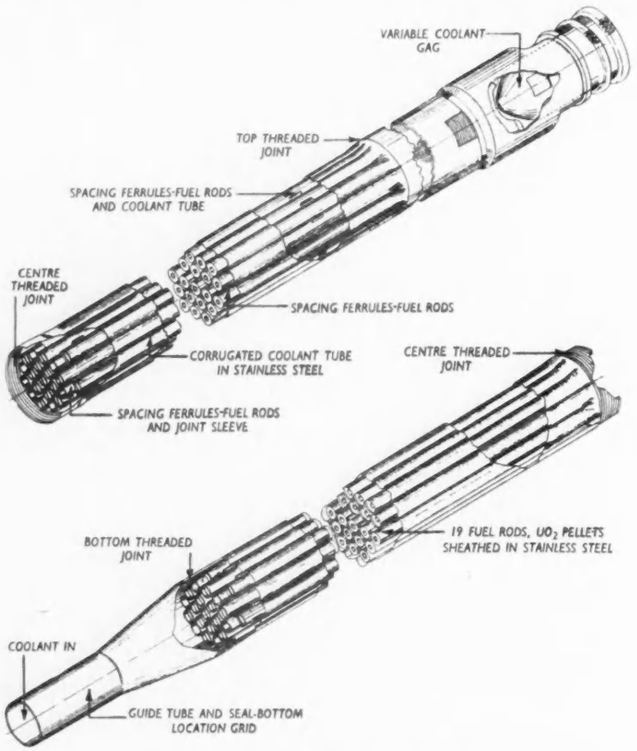

VARIABLE COOLANT GAG
TOP THREADED JOINT
SPACING FERRULES-FUEL RODS AND COOLANT TUBE
CENTRE THREADED JOINT
SPACING FERRULES-FUEL RODS
CORRUGATED COOLANT TUBE IN STAINLESS STEEL
CENTRE THREADED JOINT
SPACING FERRULES-FUEL RODS AND JOINT SLEEVE
19 FUEL RODS, UO_2 PELLETS SHEATHED IN STAINLESS STEEL
BOTTOM THREADED JOINT
COOLANT IN
GUIDE TUBE AND SEAL-BOTTOM LOCATION GRID

Fig. 3—Pictorial view of fuel element

Ship's Structure

The ship's structure is generally conventional, the main structure being framed longitudinally on horizontal surfaces, transversely on vertical. In way of the reactor room, the double bottom structure is heavily reinforced to form a seating for the reactor, its shield and its secondary shield and containment vessel. Investigation of the double bottom structure required to provide these seatings shows that there is no particular difficulty in providing both the vertical support and the lateral restraint required when the ship is in a seaway. In general, accelerations of the order of 3–5*g* have been considered.

The reactor refuelling compartment is conveniently arranged at the same width as the hatches and picks up the main deck girders associated with the hatches. Refuelling takes place through an auxiliary hatch, and the refuelling compartment has its own handling gear for handling charges in and out of the reactor itself.

Control

Analogue computer studies of a typical marine organic-moderated reactor have shown that reactor power can be safely increased from 15 to 100 per cent in fifteen minutes, allowing for restrictions imposed to promote sensibly constant temperature operation, and to ensure that safety at low power levels will be guaranteed. This rate

Specification of Reactor Plant

Core :	
Maximum heat output (including normal overload margin)	64MW
Core height	5·0ft
Nominal core diameter	5·75ft
Number of fuel channels	290
Number of fuel rods per channel	19
Fuel	UO_2
Initial enrichment	1·6 to 1·8 per cent ^{235}U
Canning	Stainless steel
Weight of uranium	7·9 tonnes
Average rating	8·1MW per tonne
Average burn-up	10,000MWD per tonne
Number of control rods	19
Primary Circuit :	
Composition of coolant/moderator	Terphenyl+30 per cent polymer
Temperature at reactor inlet	295 deg. Cent. (563 deg. Fah.)
Temperature at reactor outlet	341 deg. Cent. (646 deg. Fah.)
Maximum operating pressure	90 lb per square inch gauge
Maximum coolant flow	1294 lb per second (c. 9000 g.p.m.)
Total pumping power	322 b.h.p.
Make-up rate of terphenyl	1950 lb per day at full power
Number of primary circuits	2
Secondary Circuit :	
Total evaporation at N.S.P.	196,910 lb per hour
Steam flow to main engines at N.S.P.	160,380 lb per hour
Superheater outlet conditions	630 lb per square inch gauge/620 deg. Fah.
Final feed temperature	320 deg. Fah.

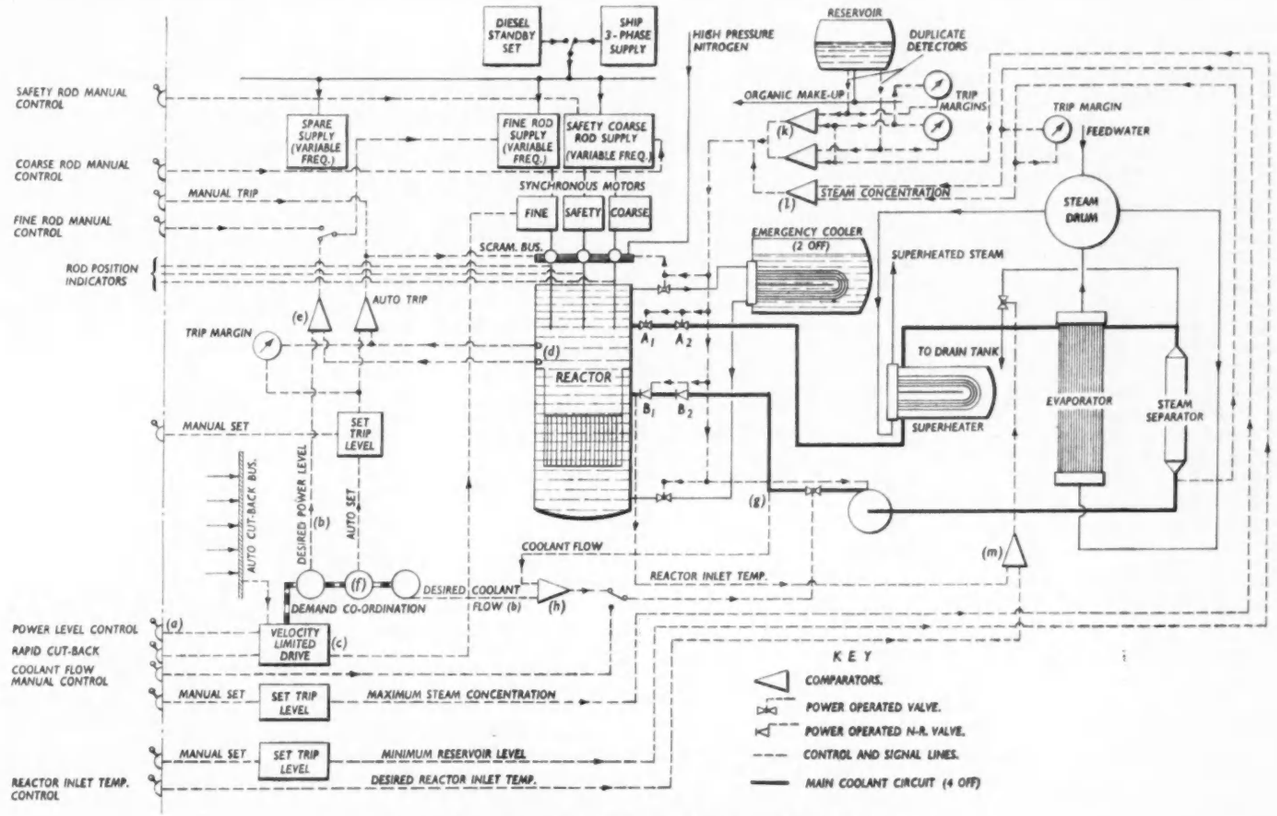


Fig. 4—Schematic arrangement of basic controls of organic moderated reactor

of power increase will cover most ship operating requirements, particularly in open water, and thus the reactor output can be matched exactly to the engine-room steam demand. To meet higher manœuvring rates a steam dumping system must be provided. While manœuvring with the dump system in action, the primary heat exchanger load will be constant and very rapid changes of turbine speed will be possible. Indeed, due to the absence of boiler problems, the nuclear ship should be easier to manœuvre than a conventional ship.

This reactor has an effective negative temperature coefficient of reactivity throughout its operating life. Thus any increase in reactor temperature causes a decrease in reactivity, lowering the neutron flux and reducing the reactor power. To make use of this inherent factor it is desirable to operate the reactor at a constant average reactor coolant temperature. This offers the possibility either of holding constant both the reactor coolant inlet and outlet temperatures during load changes over a given load range, or making these temperatures vary with load by an equal amount above and below a constant mean. The first alternative has been chosen for this design study because it gives preferable steam conditions and will cause less thermal cycling.

This system of control allows the steam pressure ahead of the turbine manœuvring valves to be held constant over the required power range, thus enabling the use of conventional machinery controls.

The maintenance of constant reactor coolant temperatures requires that, apart from slight adjustment of the control rods, the rate of flow of reactor coolant be altered according to the reactor load, and this is achieved by throttling the discharge of the constant speed primary coolant pumps. More refined methods of flow control, such as variable speed pumps, could be used at the expense of increased complexity and cost. The reactor coolant flow under power conditions is never allowed to drop below 20 per cent of its full load value so that turbulent flow conditions are maintained in all coolant channels in the core.

The return temperature from the primary heat exchangers will tend to fall as the reactor power is reduced, due to the increased effectiveness of the primary heat exchangers. To maintain the reactor inlet temperature constant a servo-operated by-pass valve is fitted across each primary circuit evaporator.

The reactor control arrangement is shown schematically in Fig. 4. The automatic section of the system is designed to operate between the limits of 20 and 100 per cent full load. The remainder of the operating range is covered by manual control which is also available at all other conditions in place of the automatic control.

The required constant coolant temperature rise in the core is obtained by co-ordinating reactor power and coolant flow to maintain these two quantities in an approximately constant ratio. The required power level is set by movement of a power level control lever (*a*), see Fig. 4, on the control desk. This simultaneously changes both the power and coolant set point (via (*b*)) at a limited rate (via (*c*)). By means of the comparator (*e*), the regulating rods are automatically set to the new operating position. Similarly, the comparator (*h*), fed by the flow signal (*g*), adjusts the coolant flow by operation of the pump throttle valves. Automatic adjustment of tripping levels is done at the demand co-ordinator (*f*), the trip margin appearing on a meter.

The desired reactor inlet temperature will be set by the operator and fed to the comparator (*m*) to control the evaporator by-pass valves.

Increasing or decreasing load will normally be effected at the prescribed rates of change. Under special or emergency conditions, the operator may change the rate restriction in order to reduce load more quickly. He is, however, prevented from changing the rate restriction in order to increase load quicker than normal, and certain fault conditions which require immediate load reduction, but not a scram, will automatically override the operator's settings.

A major fault involving loss of coolant from the primary circuit or ingress of steam to the circuit will result in automatically scramming the control rods, actuating the main reactor inlet and outlet isolating valves *A* and *B* and bringing into action the emergency cooling system. A major loss of coolant is detected by a change of level in the reservoir tank, and ingress of steam to the primary coolant circuit is detected at the steam separator. These signals are transmitted to the comparators (*k*) and (*l*) respectively, each of which can initiate the shut-down action.

To control the equilibrium xenon poisoning, it is proposed that 2·2 per cent excess reactivity is built into the core. The low core neutron flux (average thermal flux = $0{\cdot}9\times10^{13}$ n/square centimetres per second) means that no additional control is needed to over-ride xenon poisoning after shut-down, and the shut-down xenon excess is almost balanced by the effect of the fuel cooling to the terphenyl temperature of 320 deg. Cent. The build-up of samarium to equilibrium is substantially compensated by the initial rise in core reactivity due to ^{238}U conversion.

Typical start-up characteristics are shown in Fig. 5. The reactor can be brought from sub-critical to hot standby in about two hours, and is then available at any power up to its maximum.

Safety in Normal Operation

Since the reactor plant is designed to be safe in accident conditions, the margins of safety existing at normal operating conditions

are ample. The reactor is designed to be inherently stable, so that if for any reason the temperatures within the core should rise above the normal levels the reactor power will fall.

(i) *Levels of Radioactivity.*—In normal operation, there is safe and unrestricted access to all parts of the ship adjacent to the reactor containment.

The waste products removed from the primary coolant by the processing plant comprise polymer and gases, the latter being largely in the form of nitrogen and hydrogen. The polymer produced amounts to about ¾ ton per day at full power. In itself it is completely inactive, but there will be some slight activity due to impurities contained in the terphenyl feed and others which may be picked up by corrosion or erosion in the reactor plant. Based on typical impurities in the terphenyl, it is estimated that after one week's hold-up to allow the activity to decay the polymer could be discharged overboard with complete safety. Alternatively, it may be stored and discharged in port.

(ii) *Fire Risk.*—Terphenyl will burn under certain conditions, but by taking suitable precautions the fire risk can be made negligible. The flash-point of terphenyl is 194 deg. Cent., its free burning point is 220 deg. Cent., and its spontaneous ignition temperature is well over 500 deg. Cent. The terphenyl make-up store is held either in the solid or in the liquid state, always below the flash-point, in sealed containers or compartments from which oxygen is excluded by a nitrogen blanket. In the main coolant circuit the terphenyl is at a temperature above its flash-point but below the spontaneous ignition temperature. There is, therefore, no fire risk unless three simultaneous conditions are postulated, namely : a terphenyl leak, a source of ignition and an adequate supply of oxygen. It has been found by experiment that with terphenyl at 350 deg. Cent.—which is above the normal operating temperature—combustion cannot be initiated if the oxygen content of the surrounding atmosphere is below 15 per cent. The atmosphere inside the containment surrounding the reactor, primary coolant circuits, and organic processing circuits should therefore be controlled at 14 per cent oxygen. It may be noted that this atmosphere is breathable without special apparatus, should it be necessary to enter the containment. The space surrounding the containment, within the reactor room of the ship, is ventilated to atmosphere.

(iii) *Plant Reliability.*—The relatively low pressure of the primary coolant, the extensive use of mild steel and the conventional engineering of the primary circuits and processing equipment are expected to produce a reliable plant. However, all vital plant is duplicated. For example, the two main steam-raising circuits are functionally and physically separate, and a standby main coolant pump is provided. There is provided a standby oil-fired boiler with capacity sufficient to propel the ship at 12 knots.

Safety in Emergency (Internal)

Accidents arising within the reactor plant are considered below.

(i) *Reactor Control Failure.*—Extensive study of the transient characteristics has shown that the response of this plant to fault conditions is very favourable, due primarily to the large negative temperature coefficient of the fuel. The moderator temperature coefficient is also negative, except at high burn-up due to the presence of plutonium. By separating the coolant and moderator passages within the core the transient response of the reactor can be maintained strongly negative even with the positive moderator temperature coefficient.

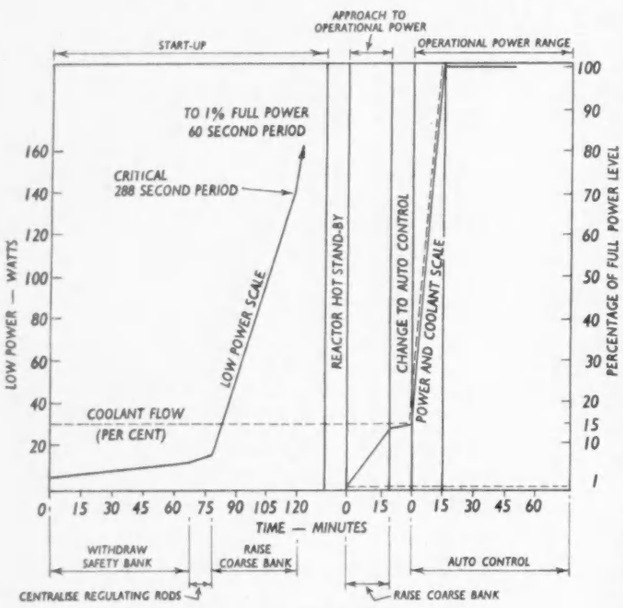


Fig. 5—Reactor availability

The control-rod withdrawal rates have been carefully chosen, following the philosophy that in the event of a fault or mal-operation a reasonable amount of time should be available in which to take action before a serious situation can develop. For example, if during start-up the control rods continue to move out after passing through critical, the reactor will not reach full power for fifty-six minutes, so that this time is available for emergency action.

(ii) *Changes in Primary Coolant Flow.*—With the reactor set at a given power level, any reduction in coolant flow will lead to a rise in core temperatures, causing reactor power to fall by virtue of the temperature coefficient. Analogue computer studies have shown that the transient temperature overshoots in the core should be well within the capacity of the oxide fuel and the stainless steel cans.

In the event of complete stopping of the main primary coolant flow, provided that the reactor can be shut down by inserting the control rods, the residual fission product heating can be dissipated by either of the emergency coolant circuits.

(iii) *Leakage of Primary Coolant.*—In normal operation the radioactivity of the primary coolant is low, being due only to the impurities present. In the event of a major leakage of primary coolant, and a rise of activity level inside the containment, the secondary shielding round the containment confers ample protection externally.

The vapour pressure of the coolant is only 6·3 lb per square inch gauge at reactor outlet temperature, so that any coolant leaking from the circuit into the containment space will not boil. This, combined with the maintenance of a nitrogen-rich atmosphere, excludes any fire hazard created by a primary coolant leak, providing that the containment envelope is still intact.

It is vital for the integrity of the core that it shall remain drowned. To this end, all coolant connections to the reactor vessel are situated well above the level of the top of the core and are fitted with quick-closing butterfly valves. Thus, if a major leak occurs external to the reactor, the valves can be shut and the reactor contents retained. The emergency coolers are designed to dissipate the core decay heat even under boiling conditions, i.e. when there has been loss of coolant from the reactor vessel and a free surface exists.

(iv) *Leakage of Water or Steam.*—The water and steam in circuit are not radioactive, so that their release into the containment space does not constitute a radiation hazard. A rupture of the steam circuit within the containment could, with continued operation of the feed pump, theoretically lead to a pressure building up in the containment equal to the steam drum pressure. Therefore, excess pressure alarms should be provided and there would then be ample time to take corrective action.

In the design considered, the steam pressure exceeds that of the primary circuit, so that the possibility exists of a leak of steam and/or water into the primary circuit. This could only occur in the heat exchangers. The most severe accident case is a fracture of an evaporator tube, when water enters the primary circuit. On entering the primary circuit, some of the water will flash due to the drop in pressure and the remainder will quickly evaporate, causing a rapid local pressure rise in the primary circuit, which in turn will tend to reduce the leak. Thus, a series of pressure surges may result. The primary circuit is not designed for the full steam pressure, and should be protected from excessive pressures by a number of relief valves, fitted in duplicate on each heat exchanger and on the reactor vessel, which could discharge to the drain tanks within the containment. It may be necessary also to increase the elasticity of the primary circuit by providing surge chambers at appropriate points.

It has been calculated that any water leaking into the primary circuit would, if it reached the reactor, be predominantly in the form of steam, and as such would cause the reactivity, and therefore the power, to drop, without giving rise to excessive fuel element temperatures.

Each primary coolant loop includes a steam separator, the purpose of which is to remove continuously by centrifugal action any small proportion of steam such as might be present due to a tube-plate weep. The separator cannot deal with a large leak, but in such an event acts as a steam detector. A steam leak into the primary circuit would not be quickly identifiable, so a signal from either steam detector is arranged to scram the reactor and isolate both primary loops by closing the duplicated inlet and outlet valves. Once the fractured loop is identified, reactor operation at 50 per cent power can be resumed on the intact loop.

The containment has been designed to take the pressure rise resulting from a major fracture of one primary loop. By isolating the two primary loops from each other by barriers of thick steel plate, it is presumed

that damage will not spread from one loop to the other. Thus, if the whole of the water and steam contents of one loop were mixed instantaneously with the whole terphenyl content of the loop, plus a quantity of terphenyl which might escape from the reactor vessel before the isolating valves closed, the resulting pressure inside the containment would be 70 lb per square inch gauge. The proposed containment is designed to take 105 lb per square inch gauge at the yield-point.

(v) *Failure of Fuel Element.*—Release of fission products from the fuel into the coolant must involve failure of the fuel can through faulty material or fabrication or through excessive stresses or temperatures.

A serious combination of faults would be loss of coolant flow at full power, coupled with failure of the reactor control system to scram. Should a core melt down occur, the molten core would burn its way through the reactor vessel and fall on to the primary shield. Penetration of the shield would result in 134 tons of water from within the shield being released into the containment and this would almost certainly cool the molten core mass sufficiently to prevent further damage. The resulting pressure rise would amount to some 30 lb per square inch gauge, so that the containment should remain intact.

The secondary shielding of the containment is designed to give limited access to the reactor room bulkheads following a major release of activity from the core. Assuming a release of 10 per cent of the gaseous fission products within the containment space, a radiation dose of 25 rems in the first five minutes after the accident would not be exceeded. The secondary shielding maintains the radiation level adjacent to the reactor room below normal tolerance when the primary circuit activity is raised by the simultaneous failure of up to thirty fuel rods.

Safety in Emergencies (External)

The most likely external emergencies to affect the safety of the reactor plant are:

(i) *Collision or Shock.*—The reactor room is situated amidships between longitudinal bulkheads 19ft from the ship's sides, which are specially designed in way of the reactor room for maximum energy absorption in the event of collision, thus minimising any distortion of the reactor room bulkheads. Further, the reactor containment envelope is 3ft clear of the reactor room bulkheads, being supported primarily by the double bottom, with secondary lateral support at upper deck level. The whole of the reactor plant is designed for shock accelerations of 5 *g* up or down vertically, 3 *g* laterally and 1 *g* fore and aft.

(ii) *Listing, Stranding or Sinking.*—The reactor plant is designed to operate at full power with a permanent list of 20 deg. The emergency coolers will operate at any angle of heel up to 90 deg. and in the stranded condition, since air is used as the heat sink. Integrity of the containment is required under all conditions to prevent the escape of fission products. Non-return valves are therefore fitted to the containment, which open when the external pressure exceeds the internal pressures by, say, 40 lb per square inch, to prevent collapse if the ship sinks.

(iii) *Fire.*—The prime requirement is to maintain integrity of the containment, since fission products may have been released within it from some prior accident. With this object, the reactor room space surrounding the containment is equipped with fire-extinguishing apparatus, with water sprays directed on to the containment and with means of flooding.

If the reactor plant and feed-water system are in working order, reactor heat can be removed in a controlled manner by the primary loops. If the air-cooled emergency coolers are in the fire zone they may be unserviceable, so that if the primary loops are also out of action the core will melt. As already discussed, the molten core will be cooled by shield water and if the containment is kept cool by water sprays or by flooding, no fission product release will occur.

(iv) *Loss of Electrical Supply.*—The maximum electrical requirement of the reactor plant at full power amounts to 370kW, of which 270kW is for the primary coolant pumps. In the event of complete failure of the normal electricity supply from the main turbo-generators, vital services amounting to 30kW are supplied by storage batteries for a five-minute period. A diesel generator of 450kW capacity, automatically started, enables full power operation to be restored as fast as reactor restart procedure permits.

Rate of Discharge of Granular Materials from Bins and Hoppers

By H. E. ROSE, D.Sc. (Eng.), Ph.D., M.I.Mech.E., M.I.C.E.,* TATSUO TANAKA, B.Eng., D.Eng.†

The rate of discharge of granular materials from storage bins and hoppers, through a circular aperture, has been investigated by the authors using small-scale models and, by means of a simple correlation curve, the results have been extended to cover the case of non-circular apertures. It is considered that the equation deduced will allow the calculation of the rate of discharge of most materials from hoppers and bins of normal type, with an accuracy sufficient for most practical purposes.

STORAGE bins and hoppers, which are used in a wide range of industries in which the handling of granular materials is involved, normally serve the dual purpose of storage of the material and of the delivery of the material at a controlled rate. These units vary widely in size, from the hoppers of small machines, such as pelleting machines, which possibly hold but a few pounds, to the storage bins for materials such as iron ore, coal, cement, &c., which might have a capacity of 10,000 tons. In all cases, however, it is essential that the design of the discharge aperture shall be such that the desired rate of discharge shall be attained, with a minimum probability of interruption of the flow by bridging of the material across the aperture.

Although the problem of the rate of discharge of granular materials from bins and hoppers has received some attention, there still remain several aspects of the subject on which the present state of knowledge is incomplete and in this article the results of an investigation, by use of small-scale models, designed to elucidate some of the outstanding problems, are presented.

The Apparatus

The apparatus used for the principal tests consists of a series of cylindrical hoppers fitted with conical bases, as shown in Fig. 1 (*a*).

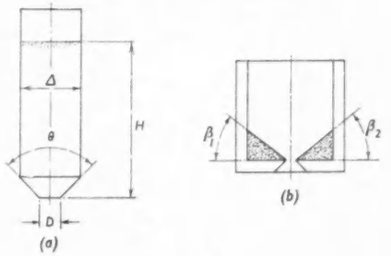


Fig. 1

The various series are such that, for example, whilst the cone angle θ is maintained constant the ratio (Δ/D) is varied or, alternatively, whilst the value of the ratio (Δ/D) is maintained constant, various values of the cone angle θ are available. Variations in the other parameters entering the problem are obtained by the use different materials of different particle shapes and sizes.

For the determination of the frictional characteristics of the granular materials, the piece of apparatus shown in Fig. 1 (*b*) is adopted. This piece of equipment consists of a pair of glass plates separated by shaped wooden spacers. The spacers form a slot which extends the full depth, from back to front, of the box, the width of the slot being considerably greater than the critical value for which bridging of the particles will occur.

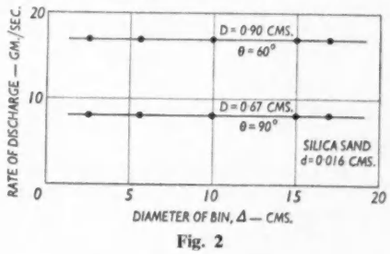


Fig. 2

In order to determine the value of the coefficient of friction of a material, the slot in the base is temporarily covered with a block of wood on the underside and the box filled with the material. The block is then removed and the arithmetic mean of the angles β_1 and β_2 gives the true angle of repose λ; even though the base of the instrument is not truly horizontal. It then follows, from simple mechanics, that $\mu_e = \tan^{-1} \lambda$; where μ_e is the effective coefficient of friction.

Theoretical Analysis

The mass rate of flow from a bin W (mass/unit time) would be expected to depend upon the diameter of the particle d, the diameter of the aperture D, and the density ρ of the material involved. It would also be expected to depend upon the coefficient of friction and the cohesive forces operative between the particles of the material μ and C respectively, the shape factor Z, applicable to the particles, upon the acceleration

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due to gravity g and also upon the height of the material above the aperture H, and upon the diameter of the bin Δ. It is also clear that the rate of flow would depend upon the cone angle θ of the base of the hopper.

These relationships can be written symbolically as

$$W=\phi[D, d, \Delta, H, C, \rho, g, \theta, Z, \mu] \quad . \quad (1)$$

where ϕ denotes a function of each of the following variables.

The application of the method of dimensional analysis to this equation leads to

$$\left(\frac{W}{D^{2\cdot5}\rho g^{0\cdot5}}\right)=\phi\left\{\left(\frac{D}{d}\right),\left(\frac{\Delta}{D}\right),\left(\frac{H}{D}\right),\left(\frac{C}{D^3\rho g}\right),(\mu),(Z),(\theta)\right\} \quad . \quad . \quad . \quad . \quad . \quad (2)$$

where the groups within round brackets ( ) are dimensionless and the meaning of ϕ is as before.

It is often possible to present the functional relationships in such a form that they enter

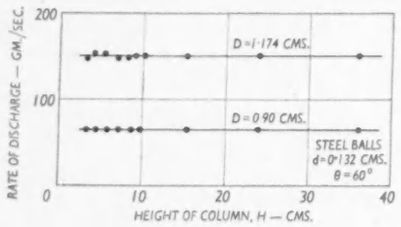

Fig. 3

as products in equation (2) in which case the equation can be written as

$$\left(\frac{W}{D^{2\cdot5}\rho g^{0\cdot5}}\right)=\phi_1\left(\frac{D}{d}\right)\times\phi_2\left(\frac{\Delta}{D}\right)\times\phi_3\left(\frac{H}{D}\right)\times\phi_4\left(\frac{C}{D^3\rho g}\right)\times\phi_5(\mu)\times\phi_6(\theta)\times\phi_7(Z) \quad . \quad . \quad . \quad . \quad . \quad (3)$$

when each of the groups on the right-hand side are, for practical purposes, independent functions.

It now remains to determine the functional relationship between the group on the left-hand side of the equation and each of those on the right-hand side.

Experimental Results

Equation (3) will now be investigated by reference to the experimental data ; each

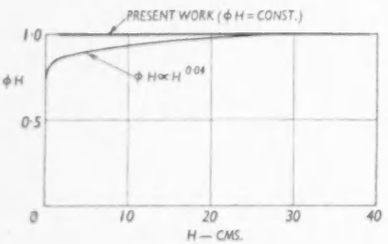

Fig. 4

group, as far as possible, being treated independently.

The Group (Δ/D).—The influence of this group has been determined by the use of a series of bins of different diameters ; the bins having a constant aperture diameter and cone angle. Typical experimental results are shown in Fig. 2 and it is seen that provided $(\Delta/D)>2\cdot6$, the rate of discharge is independent of the value of (Δ/D). Thus, for most practical bins, the rate of discharge is independent of the diameter of the body of the bin.

The Group (H/D).—The group which can be most conveniently analysed next is (H/D) and representative sets of data are presented in Fig. 3. From this figure it is seen that, provided the $(H/D)>2\cdot5$, the rate of discharge is independent of the depth of material in the bin. This is in accord with the conclusion of Hinchley,[1] who states that the rate of discharge is independent of the depth of material in the bin and roughly in accord with the results of Newton, Dunham and Simpson,[2] who state that the rate of discharge is proportional to $H^{0\cdot04}$.

In view of this divergence of opinion, it is of interest to investigate the matter further, and in Fig. 4 is shown a line corresponding to Fig. 3 of the present work, together with a plot of $H^{0\cdot04}$ adjusted so that the two lines approximate closely for the deeper beds used. From this figure it is seen that the divergence between the two curves is much greater than the scatter of the experimental points in the present work and hence it must be concluded, on the basis of this work, that the rate of discharge is independent of the depth of the material in the silo.

It is, of course, possible that, with cohesive materials, the depth of the material will have some slight effect on the rate of discharge, but for non-cohesive materials there appears to be no justification for the introduction of a term depending on the depth of the material ; especially as it appears to be generally agreed that the effect of any such term is small.

The Groups (D/d), $(C/D^3\rho g)$ *and* (μ).—The analysis of the influence of the group $d(D/)$ is complicated, to some extent, by the effects of a number of extraneous variables. Thus, for example, for a given value of the ratio (D/d), the rate of flow decreases when the size of the system is reduced to such an extent that the particle diameter d is less than about 0·2mm, since, in such cases, the effects of cohesion become significant. For this reason, the groups (D/d), $(C/D^3\rho g)$ and (μ) will be considered together. Typical data relating to silica sand and steel balls are plotted in Fig. 5 ; these data being plotted on the base of $(D/d-3)$, instead of (D/d), since if an expression of the form $(W/D^{2\cdot5}\rho g^{0\cdot5})=K(D/d-3)^n$ is used, it then follows that the rate of flow is zero when $(D/d)=3$. This

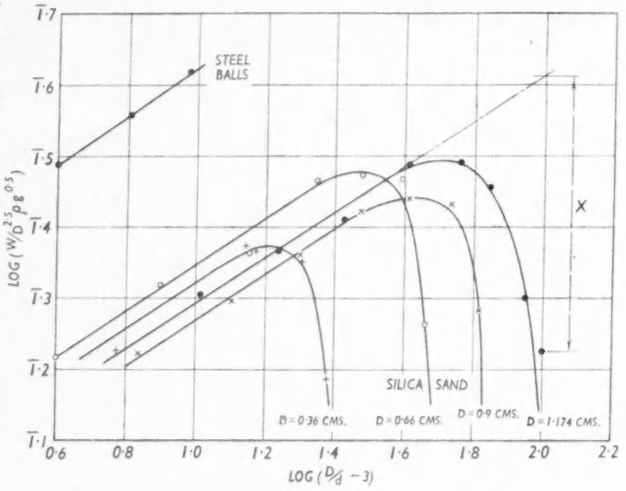

Fig. 5

result is in accord with that of Langmaid and Rose,[3] who show that bridging of an aperture occurs when the diameter of the orifice is about two and a half ball diameters.

Examination of Fig. 5 shows that the curves have two parts : a straight rising branch and a curved descending branch. Inspection of the original data, Table I, however, shows that the linear rising branch corresponds to the use of particles of diameter larger than 0·2mm, whilst, in every case, the descending branch corresponds to particles of less than this size. Thus, it may be concluded that the falling branch arises from the effects of cohesion of the particles. This view is supported by Fig. 6, in which the values of the coefficient of friction μ of various materials, as determined by the use of the apparatus of Fig. 1 (*b*), are shown. From this diagram it is seen that, for particles having diameters of less than about 0·2mm, the value of the coefficient of friction increases rapidly with decreasing particle size.

Table I

Cone angle $\theta=60$ deg. Silica sand.

Aperture diameter D(cm)	Particle diameter d(cm)	Cohesive force on particle (dynes)	Coefficient of friction	(D/d)	$(W/D^{2\cdot5}\rho g^{0\cdot5})$	log. $(D/d-3)$	log. $(W/D^{2\cdot5}\rho g^{0\cdot5})$
1·174	0·0112	600	1·25	105	0·173	2·01	1.238
	0·0133	300	0·85	88	0·197	1·93	1.295
	0·0158	50	0·71	74	0·282	1·85	1.450
	0·0204	0	0·71	58	0·305	1·74	1.483
	0·0268	0	0·72	44	0·305	1·61	1.483
	0·0391	0	0·76	30	0·256	1·43	1.408
	0·0576	0	0·86	20	0·232	1·23	1.362
	0·0910	0	0·91	13	0·206	1·00	1.312
0·90	0·0133	300	0·85	68	0·192	1·81	1.282
	0·0158	50	0·71	57	0·270	1·73	1.430
	0·0204	0	0·71	44	0·276	1·61	1.440
	0·0268	0	0·72	33	0·273	1·48	1.430
	0·0390	0	0·76	23	0·226	1·30	1.352
	0·0576	0	0·86	16	0·198	1·11	1.296
	0·0910	0	0·91	10	0·170	0·85	1.230
0·66	0·0133	300	0·85	50	0·184	1·67	1.265
	0·0158	50	0·71	42	0·294	1·59	1.468
	0·0204	0	0·71	33	0·294	1·48	1.468
	0·0268	0	0·72	25	0·290	1·33	1.460
	0·0390	0	0·76	17	0·225	1·15	1.350
	0·0576	0	0·86	11	0·212	0·90	1.326
	0·0910	0	0·91	7	0·167	0·60	1.222
0·36	0·0133	300	0·85	27	0·148	1·38	1.170
	0·0158	50	0·71	23	0·222	1·30	1.350
	0·0204	0	0·71	18	0·230	1·17	1.361
	0·0268	0	0·72	14	0·236	1·13	1.374
	0·0390	0	0·76	9	0·164	0·78	1.215

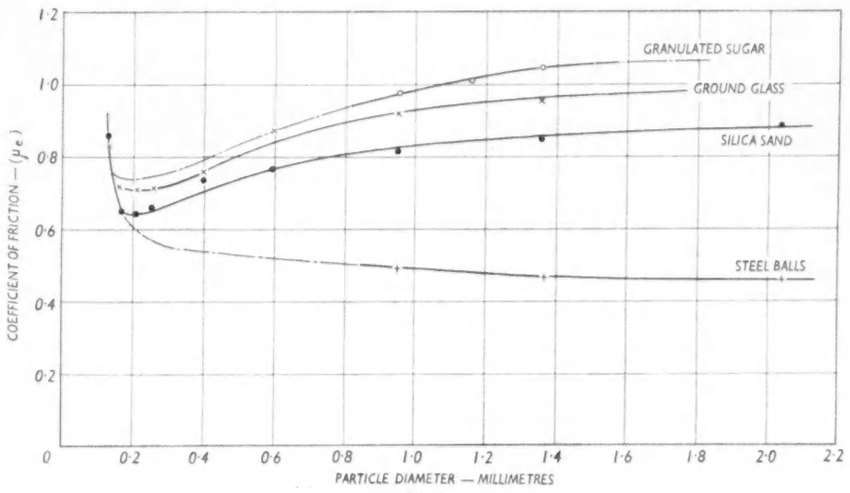

Fig. 6

Thus, reverting again to Fig. 5, the rising branch, for which the effects of cohesion are negligible, may be represented by the equation

$$(W/D^{2\cdot5}\rho g^{0\cdot5}) = K(D/d-3)^n \quad . \quad . \quad . \quad (4)$$

where n is between about 0·27 and 0·35 for the sands, and about 0·35 for the steel balls ; the average being about 0·32.

An analysis based upon more extensive data, summarised later in Fig. 12, suggests that the value of n should be about 0·3 and this value will, therefore, be adopted.

Thus, the required relationship is

$$(W/D^{2\cdot5}\rho g^{0\cdot5}) = K(D/d-3)^{0\cdot30} \quad . \quad . \quad (4a)$$

or, to summarise,

$$\phi_1(D/d) = (D/d-3)^{0\cdot30} \quad . \quad . \quad . \quad (4b)$$

Turning attention now to the descending branches of the curves of Fig. 5, the distance

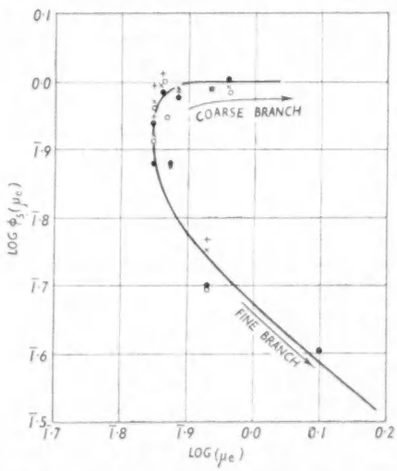

Fig. 7

X is the logarithm of the reciprocal of the factor by which the discharge, as calculated from equation (4) or 4 (*a*), must be multiplied in order to allow for the effects of cohesion on the rate of discharge of the material.

If now this factor is assumed, in the first place, to be a function $\phi_5(\mu_e)$ of the effective value of the coefficient of friction μ_e (where μ_e can depend, at least to some extent, upon the cohesive properties of the materials), then a curve of log $\phi_5(\mu_e)$ against log (μ_e) is easily determined, since the values of X corresponding to each of the points on the curves of Fig. 5 are known. The curve determined in this way is shown in Fig. 7. From this curve it is seen that the parameter $\phi_5(\mu_e)$ is practically independent of μ_e, for the coarser materials. Thus, it may be concluded that when the effects of cohesion are absent, the rate of discharge from a bin is practically independent of the coefficient of friction of the material.

For the finer branch, however, the rate of discharge is clearly not independent of the effective coefficient of friction. Since it seems to be unlikely that the true coefficient of friction would have an influence over one size range but not over the other, it is logical to expect that the variation in the discharge, over the two ranges, arises solely from cohesive effects ; that is, is dependent upon the group $(C/D^3\rho g)$. It will be noticed that the group $(C/d^2\rho g)$ used previously has, here, been changed to $(C/d^3\rho g)$. This step is valid, since for geometrically similar conditions (D/d) is constant and so one group is merely a multiple of the other, and is also logical since cohesive effects would be expected to be dependent upon the diameter of the *particle* and not upon the diameter of the discharge aperture. The cohesive forces acting on a particle C for the various samples of sand have been determined and so an examination of this relationship can be made ; the relevant data being given in Table II.

When the factor $\phi_5(\mu_e)$, determined in the way explained previously, is plotted against the group $(C/d^3\rho g)$ the curve of Fig. 8 is obtained ; these results being, as a matter of convenience, expressed as a fraction of the value for $C=0$. This curve clearly gives the relationship $\phi_4(C/d^3\rho g)$. From this curve it is seen that there is good correlation for the four different cases and hence it may be concluded, at least tentatively, that the deviation of the curves of Fig. 5 from linearity arises from the effects of the cohesion of the particles.

Thus, it has been shown that over the range of particle size for which cohesive forces are negligible, the rate of discharge is independent of the value of the coefficient of friction and also that in the size range for which cohesive forces are operative, the rate of discharge correlates well with the value of these forces. Thus, it appears safe to conclude that the rate of discharge is independent of

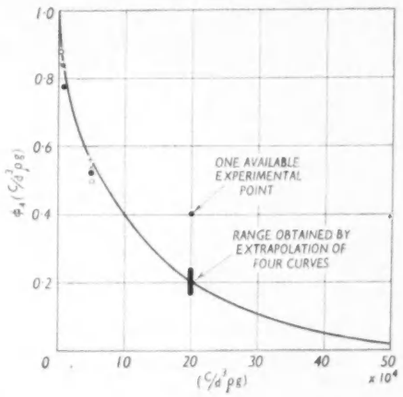

Fig. 8

the true value of the coefficient of friction of the material but depends upon the cohesive strength of the particles.

A simple analysis shows that the functional relationship $\phi_4(C/d^3\rho g)$ is given with considerable accuracy by the expression

$$\phi_0(C/d^3\rho g) = e^{-7\cdot7\times10^{-4}(C/d^3\rho g)} \quad . \quad (5)$$

Although it would be expected that the importance of cohesive bridging would depend upon the ratio (D/d), the analysis shows that, over the range examined, $16<(D/d)<100$, the effects of cohesion are

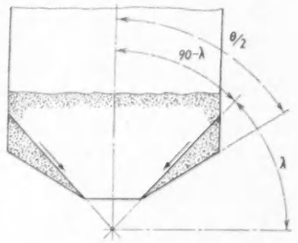

Fig. 9

independent of the (D/d) ratio. Thus, the expression above appears to be general.

The Group (θ).—The effects on the rate of discharge of variation of the angle of the cone forming the bottom of the bin will be different according to whether the angle which the side of the cone makes to the horizontal is greater or less than λ the angle of repose of the material in the bin. Thus, as shown in Fig. 9, if the slope of the cone to the horizontal is less than the angle of repose, a

TABLE II—*Based on Table I*

Material	Cohesive force on particle (dynes)	D (cm)	d (cm)	$(W/D^{2\cdot5}\rho g^{0\cdot5})$	$(C/d^3\rho g)$	$\frac{(W/D^{2\cdot5}\rho g^{0\cdot5})}{(D/d-3)^{0\cdot3}}$	$\phi_4(C/d^3\rho g)$
Silica sand	600	1·174	0·0112	0·173	200,000	0·040	0·42
	300	1·174	0·0133	0·197	50,000	0·046	0·49
	50	1·174	0·0158	0·282	5,000	0·069	0·73
	0	1·174	5 values	5 values	0	0·095*	1·0
	300	0·9	0·0133	0·192	50,000	0·055	0·55
	50	0·9	0·0158	0·270	5,000	0·081	0·81
	0	0·9	5 values	5 values	0	0·10*	1·0
	300	0·66	0·0133	0·184	50,000	0·056	0·52
	50	0·66	0·0158	0·294	5,000	0·099	0·93
	0	0·66	5 values	5 values	0	0·107*	1·0
	300	0·36	0·0133	0·148	50,000	0·057	0·56
	50	0·36	0·0158	0·222	5,000	0·091	0·85
	0	0·36	2 values	2 values	0	0·107†	1·0

* Mean of 5 values. † Mean of 2 values.

layer of granular material, which forms a funnel, is retained in the cone. Thus it would be expected that the rate of flow would be independent of the cone angle θ but dependent upon the flow characteristics of the granular medium. This case clearly corresponds to $\theta/2>[90-\lambda]$ so it would be expected that for $[90-\lambda]<\theta/2$ the rate of flow would be independent of the cone angle. When the slope of the cone is greater than the angle of repose, Fig. 9, however (that is $[90-\lambda]>\theta/2$), the granular material will slide down the metal surface and the

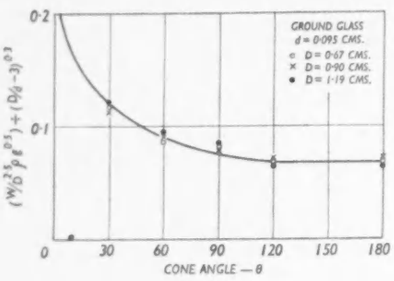

Fig. 10

rate of discharge would be expected to be dependent upon the cone angle.

A series of test results, obtained on the small scale models and correlated by the use of the data of the previous sections, are shown in Fig. 10. It is at once seen that the curve formed is in two parts : a curve of roughly hyperbolic type and a horizontal straight line—the two curves intersecting at about $\theta=120$ deg. Examination of the graph of Fig. 5 suggests that the value of coefficient of friction for glass may be taken as about 0·8, from which the angle of repose λ is $\tan^{-1}$ 0·8, which is about 40 deg. Thus, on the basis of the previous explanation, the discontinuity in the curve would be expected for the value $\theta=2(90-40)$ that is $\theta=100$ deg.; a value which is as close to the value of the observed discontinuity as can reasonably be expected.

A logarithmic plot of the co-ordinates of the falling branch on a base of log (tan $\theta/2$) shows an extremely high degree of correlation ; the equation being

$$(D/d-3)^{-0\cdot30}\times(W/D^{2\cdot5}\rho g^{0\cdot5})=K(\tan\theta/2)^{-0\cdot35} \quad . \quad . \quad . \quad . \quad . \quad (6)$$

Thus, it may be concluded that for $\theta/2<[90-\lambda]$ the rate of flow, and so $\phi_6(\theta)$, is proportional to $(\tan\ \theta/2)^{-0\cdot35}$ but for $\theta/2>[90-\lambda]$ the flow, and so $\phi_6(\theta)$, is independent of the cone angle but has the value corresponding to that given by $(\tan\ [90-\lambda])^{-0\cdot35}$.

It will also be remembered that in the previous section it was suggested that the rate of flow is practically independent of the coefficient of friction and so it would appear that, in the latter case, the rate of flow will be independent of the nature of the material ; provided the particle shapes are substantially similar.

The Group (Z).—The effect of the shape factor Z of the material has not been as widely investigated as might be desired, but, even so, there are sufficient data available to allow the general effect of this variable to be determined.

For the present purpose the ratio (f/k), as defined by Heywood,[4] will be adopted as defining the shape factor and hence Z is identical with (f/k); (f/k)=6·0 for spherical materials.

Data relating to steel balls, silica sand, powdered glass and steel discs, together with the appropriate values of (f/k), as deduced from values given by Heywood,[4] are collected in Table III.

These results are plotted in Fig. 11, and

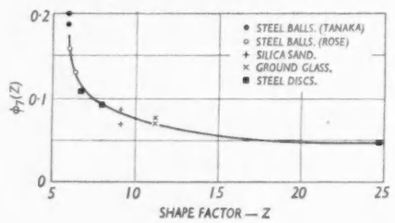

Fig. 11

examination will show that a reasonably simple empirical expression which fits these data well is

$$\phi_7(Z)=0\cdot16/(Z-5)^{0\cdot5}.$$

Thus, it is concluded that, for practical purposes,

$$\phi_7(Z)=K/(Z-5)^{0\cdot5} \quad . \quad . \quad . \quad . \quad (7)$$

It will be noticed that the two points for steel balls obtained by Tanaka, appear to be rather high, and so have been neglected in the derivation of equation (7). The remaining points, however, form a good smooth curve.

From Fig. 11 it will be seen that the rate of flow from a bin is extremely sensitive to variation in the particle shape when the particles are close to spherical, but the sensitivity decreases as the sphericity of the particles decreases.

The Final Equation

The results of the previous sections can be summarised in the form of the following equation :

$$(W/D^{2\cdot5}\rho g^{0\cdot5})=K\times(D/d-3)^{0\cdot30}\times e^{-7\cdot7\times10^{-6}(C/d^3\rho g)}\times(Z-5)^{-0\cdot5}\times\phi_6(\theta) \quad . \quad . \quad . \quad . \quad . \quad (8)$$

where the coefficient K is a constant to be determined by reference to all the available data and $\phi_6(\theta)$ are the relationships, given earlier, depending upon whether $\theta/2$ is greater than, or less than $(90-\lambda)$ deg. In

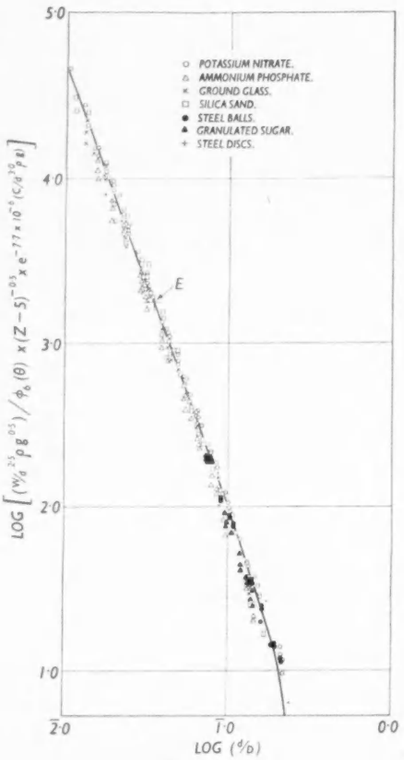

Fig. 12

Fig. 12 are plotted all the results of the present research ; together with the data of Deming and Mehring,[5] relating to potassium nitrate and ammonium phosphate fertilisers. In this curve the correlation is based on the particle diameter d, instead of the aperture diameter D, and upon the ratio (d/D), instead of ($D/d-3$), as required by equation (8), since by this means the recalculation of the numerous published data is avoided.

The points plot to form a smooth curve, but this is, in itself, insufficient to verify equation (8). However, equation (8) may be written as

$$(W/D^{2\cdot5}\rho g^{0\cdot5})\times\gamma=K(D/d-3)^{0\cdot30} \quad . \quad . \quad (9)$$

where

$$\gamma=1/\left\{(Z-5)^{-0\cdot5}\times\phi_6(\theta)\times e^{-7\cdot7\times10^{-6}(C/d^3\rho g)}\right\}.$$

Also

$$(W/d^{2\cdot5}\rho g^{0\cdot5})=(W/D^{2\cdot5}\rho g^{0\cdot5})\times(D/d)^{2\cdot5}$$

and when this is substituted in equation (9) it follows that

$$\gamma\times(W/d^{2\cdot5}\rho g^{0\cdot5})\times(D/d-3)^{-0\cdot3}=K(D/d)^{2\cdot5} \quad . \quad . \quad . \quad . \quad . \quad (10)$$

Thus, when the ordinate of Fig. 12, which is $\gamma\times(W/d^{2\cdot5}\rho g^{0\cdot5})$ is multiplied by the relevant value of $(D/d-3)^{-0\cdot3}$ and the result plotted, on logarithmic scales, against the corresponding values of (D/d), a straight line, of

Table III

Worker	Material	C (dynes)	D (cm)	d (cm)	θ (degrees)	Z	$(W/D^{2\cdot5}\rho g^{0\cdot5})$	$(D/d-3)^{0\cdot3}$	$\left[\tan\frac{\theta}{2}\right]^{-0\cdot35}$	$e^{-7\cdot7\times10^{-6}(C/d^3\rho g)}$	$\phi_7(Z)=\frac{(W/D^{2\cdot5}\rho g^{0\cdot5})\ (\tan\theta/2)^{0\cdot35}}{(D/d-3)^{0\cdot3}\times\left(e^{-7\cdot7\times10^{-6}(C/d^3\rho g)}\right)}$
Rose ...	Steel balls (ground)	0	1·590	0·318	45	6·0	0·271	1·23	1·370	1·0	0·159
Rose ...	Steel balls (as forged)	0	1·590	0·318	45	6·3	0·189	1·05	1·370	1·0	0·132
Tanaka ...	Steel balls (ground)	0	1·175	0·132	60	6·0	0·410	1·68	1·195	1·0	0·201
Tanaka ...	Steel balls (ground)	0	0·900	0·132	60	6·0	0·342	1·57	1·195	1·0	0·190
Rose ...	Steel discs ...	0	1·590	0·14	45	6·8	0·168	1·13	1·370	1·0	0·108
Rose ...	Steel discs ...	0	1·590	0·12	45	8·0	0·256	1·95	1·370	1·0	0·095
Tanaka ...	Silica sand ...	50	0·900	0·016	60	9·0	0·290	3·30	1·195	0·90	0·074
Tanaka ...	Silica sand ...	0	1·175	0·091	60	9·0	0·204	2·00	1·195	1·0	0·086
Tanaka ...	Ground glass	0	1·190	0·095	60	11·0	0·186	2·00	1·195	1·0	0·076
Tanaka ...	Ground glass	0	0·670	0·095	60	11·0	0·140	1·54	1·195	1·0	0·075
Rose ...	Steel discs ...	0	1·590	0·260	45	25·0	0·087	1·39	1·370	1·0	0·045

slope 2·5, will result, if equation (8) is applicable.

When this procedure, for a series of points along the " best line " of Fig. 12, is carried out, the curve of Fig. 13 is obtained.

It is at once seen that the line is straight, over the whole range, and has a slope of 2·48, which is close to the expected value of

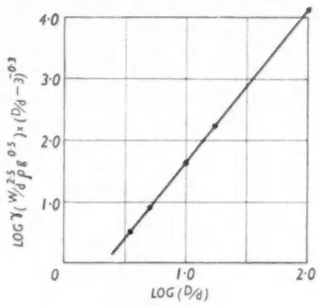

Fig. 13

2·5. Thus, the data of Fig. 12 are in close agreement with the results of the present research, as represented by equation (8).

The Constant K

There now remains to evaluate the constant K, a step which is essential if the results are to be used for the practical calculation of the rates of discharge from a bin. For this purpose consider the representative point, marked E on Fig. 12, where

$$(W/d^{2\cdot5}\rho g^{0\cdot5})\times(Z-5)^{0\cdot5}/\phi_4(C/d^3\rho g)\times\phi_6(\theta)$$
$$=1780 \text{ and } (d/D)=0\cdot036.$$

Then

$$(D/d)=27\cdot8, \text{ so } (D/d-3)^{0\cdot3}=2\cdot71$$
$$\text{and } (D/d)^{2\cdot5}=4150.$$

Thus

$$1780=K\times2\cdot71\times4150 \text{ or } K=0\cdot160.$$

Thus the equation of discharge becomes

$$(W/D^{2\cdot5}\rho g^{0\cdot5})=0\cdot16(D/d-3)^{0\cdot3}$$
$$\times\phi_6(\theta)\times(Z-5)^{-0\cdot5}\times e^{-7\cdot7\times10^{-4}(C/d^3\rho g)} \quad . \quad . \quad . \quad . \quad (11)$$

The value of $(\tan\theta/2)^{-0\cdot35}$ is to be used for $\phi_6(\theta)$ only for the range $\theta/2<[90-\lambda]$. For $\theta/2>[90-\lambda]$ the value $\{\tan[90-\lambda]\}^{-0\cdot35}$ must be used.

Furthermore, for particles greater than about 0·3mm diameter, the effects of cohesion are negligible and so the term $e^{-7\cdot7\times10^{-4}(C/d^3\rho g)}$ may be taken as unity.

Finally, for D/d reasonably large, the term $(D/d-3)$ may be replaced by (D/d) with negligible error (e.g. when $D/d=12$ the error in $(D/d-3)^{0\cdot3}$ introduced by this substitution is 8 per cent).

With these simplifications the equation becomes

$$(W/D^{2\cdot5}\rho g^{0\cdot5})=0\cdot16(D/d)^{0\cdot3}\times\phi_6(\theta)\times(Z-5)^{-0\cdot5} \quad . \quad . \quad . \quad . \quad . \quad (12)$$

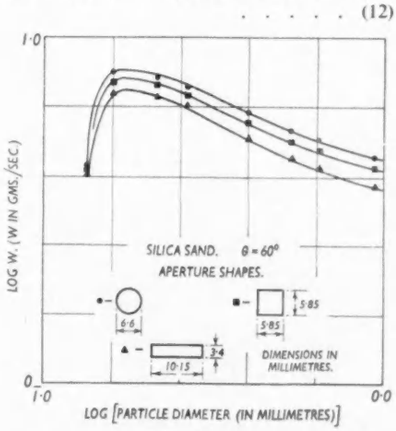

Fig. 14

Extension to Discharge Apertures Other Than Circular

A limited number of tests have been carried out with discharge openings having the same area, but of various shapes, these data being shown in Fig. 14. It is necessary to correlate the data in some reasonably simple way, and since it is clear that the aperture will bridge

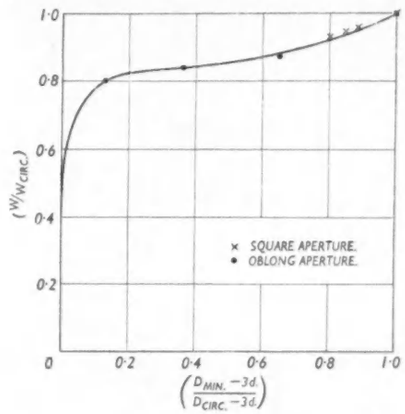

Fig. 15

when the minimum dimension D_{min} is about equal to three particle diameters, it is suggested that a reasonable basis for correlation is

$$\left(\frac{D_{min}-3d}{D_{circ}-3d}\right)$$

where D_{circ} is the diameter of a circular aperture of the same area as the non-circular one. Furthermore, the rate of discharge W may be expressed as a fraction of W_{circ}, the rate of discharge of a circular aperture of the same area. When the data of Fig. 14 are correlated on this basis the curve (Fig. 15) is obtained and this curve may be used to deduce the discharge from apertures of other than circular form. Thus, the rate of discharge from a circular aperture of the same area is calculated from equation (11) or (12), and the discharge from the non-circular aperture computed from it by reference to Fig. 15.

Example

A coal bunker has an average cone angle θ of 60 deg. and the exit aperture is 24in square. The coal to be handled has a " mean " diameter of 4in, a specific gravity of 1·6 and the shape factor Z may be taken as 8. The angle of repose for the coal may be taken as 45 deg. Estimate the rate of discharge.

The diameter of a circular aperture of the same area is 27·1in, so

$$D/d=6\cdot8 \text{ or } (D/d-3)^{0\cdot3}=1\cdot495,$$

$$\lambda=45 \text{ deg.} \quad \frac{\theta}{2}=30 \text{ deg., so } \theta/2<(90-\lambda).$$

Hence

$$(\tan\theta/2)^{-0\cdot35}=(\tan 30)^{-0\cdot35}=1\cdot21,$$
$$Z=8, \text{ so } (Z-5)^{0\cdot5}=1\cdot73.$$
$$C=0, \text{ so } e^{-7\cdot7\times10^{-4}(C/d^3\rho g)}=1\cdot0.$$

Then

$$W=\left\{\left(\frac{27\cdot1}{12}\right)^{2\cdot5}\times1\cdot6\times62\cdot5\times32\cdot2^{0\cdot5}\right\}$$
$$\times0\cdot16\times1\cdot495\times1\cdot21\times\frac{1}{1\cdot73}$$
$$=7\cdot65\times1\cdot6\times62\cdot5\times5\cdot62\times0\cdot16$$
$$\times1\cdot495\times1\cdot21\times\frac{1}{1\cdot73}$$
$$=720 \text{ lb per second.}$$

Now

$$\left(\frac{D_{min}-3d}{D_{circ}-3d}\right)=\frac{24-12}{27\cdot1-12}=0\cdot8$$

and from Fig. 15, when

$$\left(\frac{D_{min}-3d}{D_{circ}-3d}\right)=0\cdot8 \quad \frac{W}{W_{circ}}=0\cdot91$$

so

$$W=W_{circ}\times0\cdot91$$
$$=720\times0\cdot91$$
$$=650 \text{ lb per second.}$$

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Electrical Inspection Directorate

When the inspection organisation of the Ministry of Supply was regrouped functionally, a new body known as the Electrical Inspection Directorate was set up in 1958 *to be responsible for the inspection of all electrical equipment and instruments supplied by the Ministry. The new directorate operates through its headquarters and laboratories in Bromley, Kent, and an inspection staff divided into five regions covering the whole country. A brief outline of the history and functions of the directorate is given here.*

THE Electrical Inspection Directorate which was open to visitors on October 14 and 15 is a comparatively new organisation. It was set up in 1958 when the inspection service of the Ministry of Supply was reshaped as a result of recommendations made by a committee under the chairmanship of Sir Cyril Musgrave. The purport of these recommendations was that inspection should be reorganised to concentrate allied techniques instead of having separate establishments providing individual service to users, as was the previous practice.

Accordingly, the electrical and instrument sections of three old-established inspectorates were taken and amalgamated to form the new Electrical Inspection Directorate. One was the Aircraft Equipment Division of the Aeronautical Inspection Directorate (A.I.D.) which, it may be recalled, came under the control of the Ministry of Supply in 1945. The second contribution came from the Fire Control Instrument section of the Inspectorate of Armaments: this section originated in 1895 with the early efforts made by the Royal Carriage Department at the Royal Arsenal to provide instruments whereby gunfire could be observed and corrected. The third element in the amalgamation was the Inspectorate of Electrical and Mechanical Equipment which originated in 1889 in Woolwich Dockyard, with the establishment under War Office control, of the Inspectorate of Royal Engineer Stores.

In the reorganised inspection service of the Ministry of Supply, the Electrical Inspection Directorate (E.I.D.) became responsible for the inspection of all electrical equipment and instruments supplied by the Ministry.

Broadly, the functions of the E.I.D. are executive inspection and technical direction. Thus, inspection of Ministry stores during manufacture is the responsibility of a widespread regional organisation under technical

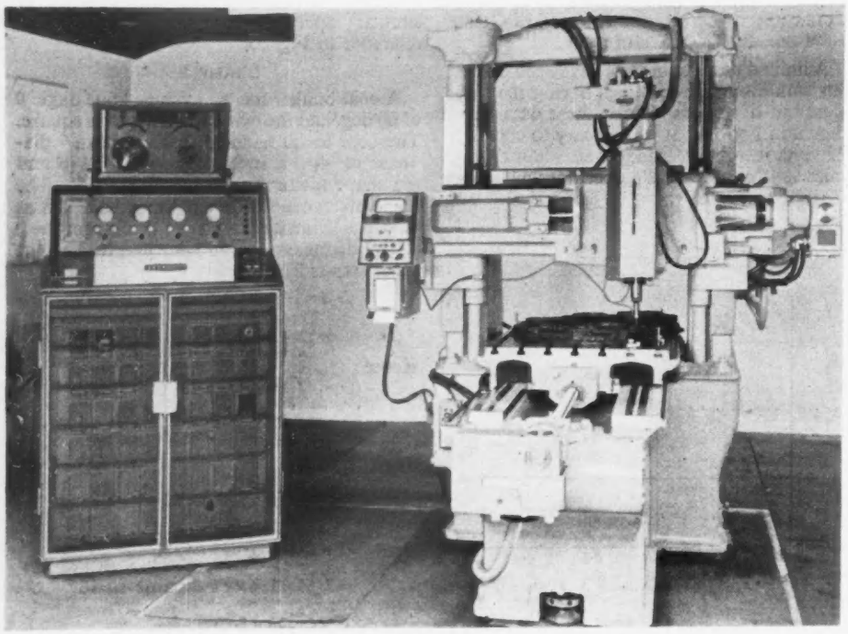


Fig. 1—Three-dimensional tape-controlled measuring machine. Overall accuracies better than ±0·001in on dimensions up to 18in are obtainable: measuring capacity of machine is 30in by 20in by 7in

direction from the inspectorate headquarters. Technical direction is exercised by a number of specialist officers, each responsible for a particular technique.

The function of technical direction is also associated with pre-contract work and post-design control. Pre-contract work includes the tendering of advice, particularly on the maintenance and inspection aspects of proposed designs and prototypes. Post-design control mainly involves Army equipments and implies full technical control of an equipment as soon as it has been released for production. As part of this service the directorate studies all defect reports from users and prepares any draft instructions for modifications to remedy such defects. Equipment defect reports are also studied on behalf of the Royal Air Force, but the E.I.D. is not responsible for preparing the subsequent modification instructions.

Under its director, Brigadier C. A. Zweigbergk, the E.I.D. is organised in three main divisions, each of which is sub-divided into a number of branches as summarised in the accompanying table. In addition to these divisions there is a regional panel which is responsible to the director for the regional organisation covering five regions. The headquarters and main laboratories are at "Aquila," Bickley, Bromley, Kent.

To deal with all these varied activities would be beyond the scope of this article and we propose to confine our remarks to a few of the many interesting things we saw during our brief tour of the directorate and to concentrate particularly on those developments in metrology and inspection to which the E.I.D. has made significant contributions.

Three-Dimensional Tape-Controlled Measuring Machine.—About three years ago, when tape-controlled milling machines were coming into use in Great Britain, it was foreseen at the E.I.D. that the fitting of a universal measuring head instead of the cutting tool would provide the basis of an automatic dimensional measuring machine. The head, under tape control, could be made to track round the true shape of a component, and to indicate/record any errors in shape. This measuring head would require to be accurately responsive to movement in all planes, but no such equipment was on the market. In 1957 the E.I.D. designed and made a prototype* which showed promise, and it was tried out against a known test piece on a Ferranti tape-controlled production milling machine. The results were promising and it was decided to convert an existing conventional machine tool into a fully automatic inspection machine, taking every precaution to improve its accuracy, friction losses and backlash. As a result, the machine shown at Fig. 1 has been built and installed at "Aquila."

The measuring head with a standard proprietary indicator and recorder is a self-contained measuring system which has many applications apart from this machine. Laboratory tests show accuracies in the order of ±0·00005in over ±0·005in range which can be varied from ±0·0005in to ±0·015in.

Basically the machine is the framework of a jig boring machine, with the slideways table and cross slide reworked and converted to run on air bearings. The lead screws have been replaced by recirculating ball nuts and lead screws of a special design to eliminate backlash. The normal borer quill bearing housing carried on the cross slide has been replaced by a new design to give controlled vertical movement to the measuring head.

Standard Ferranti machine tool control equipment, including servo-motors and gearboxes, are fitted to all three lead screws, in *X*, *Y* and *Z* axes, together with diffraction grating units, providing the feed-back to this closed loop system. The control cabinet incorporating the tape deck unit is shown in Fig. 1 next to the machine.

The measuring capacity of the inspection machine is 30in by 20in by 7in. Overall accuracies better than 0·001in are being obtained on dimensions up to 18in. Development is proceeding to study the versatility and improve the accuracy.

Experimental Automatic Co-ordinate Measuring Machine.—Another interesting development is that of an automatic co-ordinate measuring machine using preset dials and diffraction gratings with photocell sensing elements and electronic decimal counters. The equipment (Fig. 2) consists of the E.I.D. measuring head (No. 1, Mk. 1)

* Institution of Mechanical Engineers. *Proceedings of Conference on Technology of Engineering Manufacture.* March 1958. Paper No. 27. Page 607.

Scope of Electrical Inspection Directorate

Engineering Services Division :
- Electronic Services Branch,
  - Standards and test gear
  - Technical training
- Metallurgical Branch,
- Packaging Branch,
- Technical Services Branch,
  - Metrology
  - Workshops
  - Drawing-office
  - Printing and photography

Power and Instruments Division :
- Computer Branch,
  - A.A. predictors and fire control systems
  - Aircraft flight control, navigation equipment and simulators
  - Bomb-sights and computers
  - Inertial navigation systems
  - Data transmission systems
- Electrical Branch,
  - Electrical transmission, distribution and installation equipment
  - Lamps, industrial and domestic appliances
  - Instruments and aircraft electrical equipment
- Optical Branch,
  - Artillery optical instruments
  - Photographic, cinematographic and survey instruments,
  - Map reproduction equipment
- Power Branch,
  - Generators and motors (airborne and ground service)
  - Oil engine test

Electronics Division :
- Atomic Weapons Branch,
  - Fusing and firing systems
  - Mechanical and environmental test services
- Electronic Components Branch,
- Radar Branch,
  - Army radar equipments
  - R.A.F. ground and airborne radar
  - Navigational aids
  - Meteorological radar
  - Searchlights
- Signals Branch,
  - Army and R.A.F. ground and airborne wireless communications, telemetry, C.W. jammers and sonobuoys
  - Line communication and telegraph equipment
  - Vehicle installations
  - Wireless and radar test equipment
  - Nuclear reactor instrumentation

Note : With regard to the products dealt with by the various branches this table is indicative rather than exhaustive.

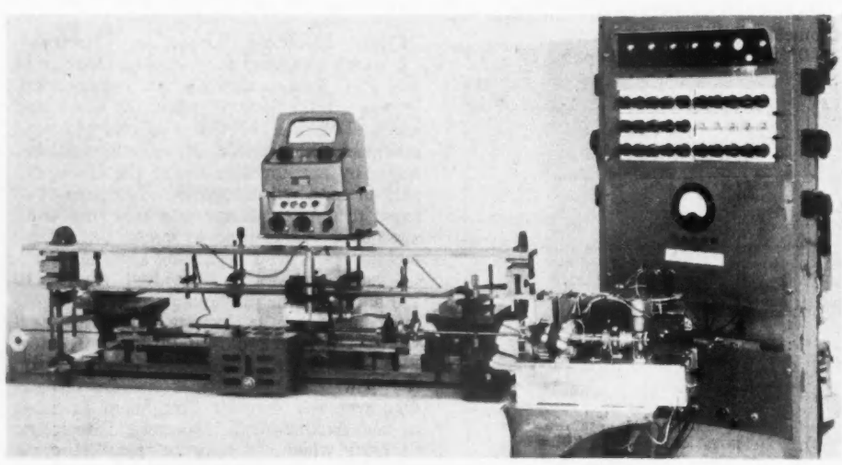


Fig. 2—Experimental automatic co-ordinate measuring machine using preset dials, diffraction gratings with photocell sensing system, and electronic decimal counters

mounted on a small carriage to which is also attached a photocell sensing element. The carriage is traversed longitudinally with very little friction in the *X*-axis by a lead screw driven by two motors, one motor driving at 8in per minute and the other driving through a gear at $\frac{1}{2}$in per minute. The photocell sensing element consists of a lens and four photo-transistors equally spaced above a diffraction grating, fitted along the length of the slide. These transistors generate signals as the light reaches them from the moire fringe pattern produced, four separate signals being generated for each of the 2500 lines per inch of the grating. These signals are passed to a decimal counter made up of five visible decatron counter tubes in line as a decimal display and recording in 0·0001in up to 9·9999in, the tubes being numbered from 0 to 9 around the periphery of their domes. A reading is made by comparing the discharge glow on the ten cathodes with the numerals. The maximum counting rate of the counter is 1250 lines per second, or $\frac{1}{4}$in per second, the speed at which the counter works (8in per minute) being well within this maximum speed.

Quadrature waveforms from the photocell sensing elements are passed to the photocell amplifier and then to the squaring, pulse-forming and gating circuits, which produce pulses in correct relationship to operate the decatron counter tubes, adding or subtracting according to the direction of travel of the measuring head and carriage. Two separate monitor and check tubes on the counter enable these signals to be continuously monitored for phase relationship and accuracy respectively during operation.

Tappings are taken from each cathode of the decatron tubes to five banks of five switches, a six-way uniselector selecting the bank of switches required. The measurement information from the selected switch bank is passed by the uniselector through a transistor gate to a relay system which controls the fast and slow motors.

With this arrangement it is possible to preset a programme of five movements from 0in to 9·9999in in 0·0001in increments. Then, when the machine is switched on, it will complete this programme automatically or follow any continuous programme obtained by continuously resetting the dials whilst the machine is operating. The present dimensional limit of 0in to 9·9999in can be extended to any desired length by adding decatron tubes and the necessary switching gear. The diffraction grating in the present equipment is 30in long.

It is found that the measuring accuracy in the one plane is the product of the functioning time of the relay gating system associated with the decatron counters, and the overshoot time taken up in overcoming the momentum of the motors. This error in time totals 12 milliseconds and is made up of 8 milliseconds relay functioning time and 4 milliseconds overshoot time, the error in inches being 0·0001in.

With a correctly arranged programme of co-ordinate dimensions, it will be possible to arrange almost unlimited measuring programmes in the *X*, *Y* and *Z* axes, the programme being set by merely presetting the dials to the measurements required and setting the time switches to allow the movements to take place. The measuring head itself is coupled to the standard indicator and recorder, thereby enabling all dimensions measured to be recorded on the charts.

Valve Vibration Test Equipment.—Test equipment for vibration noise, fatigue and resonance search tests on the "reliable" series of electronic valves is shown in Fig. 3. In fatigue tests particular attention is paid to the incidence of heater failures. Heaters are switched on and off during the run, which lasts for ninety-nine hours, thirty in two planes and thirty-nine in the other, thus simulating conditions of use.

The vibration noise test is carried out in those applications which require control of noise caused by vibration or microphonic effects. The test is usually done at one fixed frequency of vibration and at some minimum value of acceleration, usually 2*g*. An extension of this test is the resonance search test, in which the frequency spectrum is explored to determine the position of mechanical resonances which manifest themselves as increases in the anode voltage of the valve under test. In practice, the vibration frequency used to apply a sinusoidal acceleration to the valve is varied automatically from 0 to $2\frac{1}{2}$ kc/s in a minimum specified time. The anode voltage variations from the valve under test are continuously monitored and recorded during the frequency sweep, and if a resonance exists it will be shown on the recording paper.

Valves under test are mounted in vibration heads (left, Fig. 3). To minimise the transmission of vibration these heads are supported on an isolated concrete plinth.

The heads will accommodate eight or twenty-four valves and are fitted with barium titanate crystal accelerometers. The accelerometer outputs are fed through coaxial leads and sockets to the input terminals of four cathode-follower units, providing an impedance match. Each of these cathode-followers feeds an attenuator calibrated in terms of peak acceleration. Any one of the four outputs can be selected at a coaxial patch panel and fed into the main control amplifier, which indicates the output voltage proportional to accelerometer output on a panel meter. The control amplifier also provides a control voltage which is used to regulate a compressor circuit in a Brüel and Kjoer beat frequency oscillator (type 1014). The output from the oscillator is amplified by a stage capable of delivering up to 1000W maximum power, which is used to drive the moving coils in the vibrator heads. The oscillator frequency control is varied over the range 20 to $2\frac{1}{2}$ kc/s by a motor which also drives a recording chart logging the noise output voltage from the valve under test. Thus constant acceleration can be applied over the frequency range used during resonance search tests.

Current Regulator, 1A to 800A.—Among the many interesting equipments in the Electronics Services Branch we noticed a current regulator specially designed for controlling currents from 1A to 800A d.c. and 50 c/s at 6V maximum. On direct current the supply is from a bank of secondary batteries and on alternating current it is from a specially constructed transformer unit with automatic coupling to the regulator and safety switching devices. These devices are so designed that it is virtually impossible to break the supply of secondary current before reducing the "Variac"-controlled primary voltage to zero. The regulator contains eight individual heavy-duty variable-resistance units, each independently placed into circuit and varied in value by means of a rotary stud switch. The resistance units are housed in sealed metal containers for cooling by forced air draught in conjunction with a heat exchanger consisting of an upper and lower water tank connected by a number of small tubes over which forced air is continuously circulated.

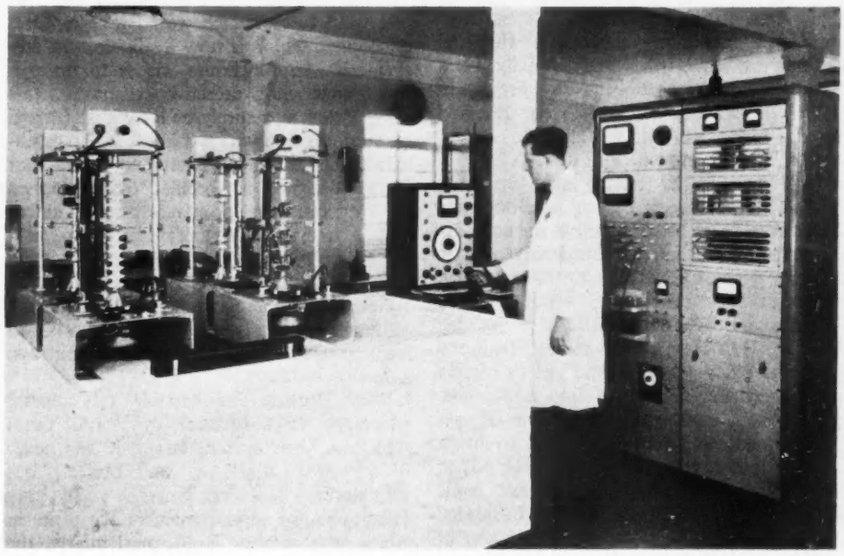


Fig. 3—Vibration test equipment for electronic valves. It can be used for fatigue tests and vibration noise tests, including search for resonance

The rotary stud switches are so marked to provide sequential operation and the regulator gives a stable and fine control of current over its range. A vernier unit for the control of low current below 1A can be used in conjunction with this regulator.

Stable Source of Infra-Red Radiation.—The inspection of infra-red photo-cells in the Optical Branch calls for a stable source of infra-red radiation and equipment has been designed to minimise the many variables. The temperature of the radiator is held to less than ± 1 deg. Cent. variation by a platinum resistance controller and measured by means of a platinum-platinum rhodium thermocouple and a potentiometer. To eliminate the thermal radiation of the background, the aperture, shutter, path length and receiver mounting are surrounded by a circulating water system at 20 deg. Cent. To avoid selective absorption by carbon dioxide and water vapour, the air in the path length can be replaced by feeding in dry nitrogen. The radiator output is chopped sinusoidally, whilst that of the photo-cell is fed into a narrow band amplifier.

LETTERS AND LITERATURE

Letters to the Editor

(We do not hold ourselves responsible for the opinions of our correspondents)

ISAMBARD KINGDOM BRUNEL

SIR,—To Mr. Newhouse's contentions I will endeavour to make suitable replies.

(1) Whilst conceding that Brunel was not always a profitable man to follow, it cannot be urged seriously or sustained that every enterprise in which he was involved became financially unwound due to his lack of administrative ability or even that he caused more money to be lost than gained. Naturally, disappointed shareholders exercised their right to object to failures, but there were doubtless many busybodies who had nothing at stake who were equally vociferous. Also, if there was any project in which Brunel was an initiator or retained by the principals which failed to attract capital, I have yet to hear of it.

(2) I have read (many years ago) the official biographies of our subject, but have discounted them as to my mind the contents of such works are as unreliable as the modern process of debunking is unworthy. Amongst the sources on which I place reliance are MacDermot's *History of the G.W.R.*, Rolt Hammond's recent biography (whereof I have checked and agreed certain references) and *The Great Iron Ship*. Mr. Newhouse's attempted conversion of my points concerning Scott Russell as a reliable witness into a criticism of a bygone I.C.E. Council is ingenious but one must come back to the point that a man whom he quoted as an authority is shown to be unworthy of credence.

(3) Brunel certainly had a gift of expression akin to that of Mr. Gilbert Harding, and like our contemporary he applied it when the need was apparent. Being capable of working a twenty-hour day for considerable periods (although he did not like it, if one may judge from a document quoted in *History of the G.W.R.*), Brunel expected and demanded like services from others. It would be interesting to receive authentication of the opinion that Surveyors would not take or retain service with Brunel. In any case, there would not be a pool of skilled surveyors in the country in the early days of the railways. Further, Brunel was also and simultaneously concerned with such activities as interviewing individual owners, addressing meetings, preparing evidence for the Bill, and reporting to, and working in collaboration with, Saunders. Much of this work was administrative, and so well was it done that the Bill was passed at its second presentation.

(4) Although Contractors found that Brunel was an uncomfortable taskmaster, it must also be borne in mind that there was never a lack of tenderers, and that Brunel never shirked the unenviable task of taking unfinished works under his own direction.

(5) Concerning the discrepancy between calculated and actual position of "The Great Iron Ship" although I am not a navigator, I can suggest causes which do not make reflections upon the Commander (the ship was always fortunate in attracting a particularly good Master). Navigational aids would include sounding gear, apparatus for making celestial observations, and magnetic compasses, all of best mid-nineteenth century design and manufacture. We may assume that there was no occasion to be "swinging the lead" on a transatlantic run, but it may well have been that for a considerable period there was no opportunity to take observations due to cloud and that navigation would be by dead reckoning. A century ago there was obviously not that knowledge of ocean currents and wind forces which would take a vessel off course, which is now available. In any event, if Mr. Newhouse wishes to make a point concerning defective compasses, this information may surely be located in (Board of Trade ?) archives, and if he should establish that, he will still have to prove that Brunel designed or specified the compasses or overrode the opinions of instrument makers or navigators, before he can be held blameworthy.

(6) The opinion that Brunel consistently adopted the "haul up the ladder, Jack" attitude is one of which I should wish to have specific evidence before accepting it as a fact.

That Brunel was capable of colossal effrontery is illustrated by "100 Years Ago" in your current issue. It has never been urged that he was perfect, but his stature was monumental. In any assessment, we must remember the times in which our subject lived, particularly the commercial practices and morality which obtained. That he was in the end overpraised, and that his official biographers glossed over his errors was common enough a hundred years ago. What is uncommon even in these times is that a lifelong opponent of the calibre of Mark Huish (who was a financial thug and consistently hard and sharp character) should without hope of any gain set about the work of getting the Clifton Suspension Bridge erected as a fitting memorial to a departed adversary.

If Mr. Newhouse will cite chapter and verse for his opinions, I will (if you permit) reply, though already I have twice disregarded Dr. Johnson's dictum and my own rule.

G. F. R. DICKINSON

Baildon, Yorks,
October 12, 1959.

ELEGANT STRUCTURES

SIR,—The recent statement by the contractors of the Chiswick flyover coupled with the pictures recently released of the Bell Weir Bridge over the Thames have both highlighted the extraordinary love of massive inelegant structures shown by some ultra-conservative British engineers, particularly those retained by the M.T.C.A. In the past your paper has given some outstanding examples of really elegant civil structures employing the best modern techniques, many, alas, designed by foreign engineers. Apparently neither Continental nor American engineers are afraid to use these recently developed techniques. I would cite only two examples, that of the steel road bridge over the River Blanco in Mexico (THE ENGINEER, Volume 197, page 131), and that of the Unkelstein viaduct between Bonn and Remagen. Comparing the latter with the Chiswick flyover is a worthwhile exercise.

Perhaps I am old-fashioned but I was always taught that if an engineering design did not look right the chances were that it was not right. I would like to suggest an extension to this, that if a design is not elegant it is probably not the best way of achieving the required result. For British engineers, only the best is good enough. Please may we have more elegance in our designs. A thing of beauty is a joy for ever but an inelegant structure is, equally forever, a blot on the landscape.

D. MAITLAND

Witham, Essex,
October 14, 1959.

REDESIGNED LIGHT CAR

SIR,—Mr. Turner in his letter that you published on October 16 complained of the difficulty of entering and leaving the modern low cars. Another and equally annoying consequence of the tendency to make motor-cars look like tortoises is the resulting bad visibility in any direction above the horizontal. I have just had occasion to choose a new car : the make I chose was the only one I could find that was otherwise suitable, that from the driving seat gave me at least a glimpse of the sky.

C. J. O. GARRARD

London, N.W.3,
October 16, 1959.

SIR,—Hurray for Mr. T. Henry Turner's letter of October 10, and why please do designers of small cars imagine that drivers have tiny feet ? Surely pedals should, within limits, be made to suit at least size eight shoes.

H. W. SCOTT

Lochwinnoch,
Renfrewshire,
October 16, 1959.

Book Reviews

Symbolic Logic and Intelligent Machines. By E. C. BERKELEY. Reinhold Publishing Corpn., New York. Chapman and Hall, Ltd., 37, Essex Street, London, W.C.2. Price 52s.

THIS book treats Boolean algebra and its application in the form of Shannon's work on switching theory. The author starts with a brief general survey of logic and then presents Boolean algebra very informally, illustrating with various linguistic and numerical interpretations. He later gives a more rigorous treatment, using an axiomatic foundation.

In Chapters 7 to 12 he examines relay-switching circuitry applied to problems of growing complexity until he reaches the construction of adders, multipliers, &c., for

calculating. In the course of this discussion he offers examples of what he calls "intelligent" machines, under which he classifies such things as railway signals, automatic telephones, as well as digital computers. Most of the machines are fairly simple and there is no discussion of simulating the more complex branches of human behaviour. Chapters follow on a Boolean algebra with various time operators, most of which could be handled with the ordinary existential quantifier and a single time operator. The book closes with a chapter relating mathematical logic to programming.

The book is, in some ways, a good introduction. To present Boolean algebra step by step together with an interpretation is a sensible concession to the reader. The exposition is extremely readable and generally very clear. However, the title is somewhat misleading. One might fairly have expected more mention of other logical calculi, especially many-valued logics, important in such applications as time-table problems, but Berkeley does not go beyond Boolean algebra. Obviously, a book of this kind cannot treat all this in any detail, but scarcely to mention them seems wrong. The title also suggests that some description of neural nets and the work of McCulloch and Pitts, Turing machines, finite automata, and the general subject of cybernetics would be included. There is also no description of the concepts of feedback and programme modification, vital in this field. These are considerable defects in an introductory book.

A subsidiary thesis appears to be that logic represents the process of thinking and that, as a result, arguments could be solved by machine calculation (page 19). This is an arguable theory which has been held by some very distinguished thinkers, notably Leibnitz. Mr. Berkeley would agree that successful argument so often depends on the complex weighing of evidence, sorting out of ambiguities, &c., that no present-day computer could ever do this and that it would take a computer with the brain power of an intelligent human being to solve most of our problems in argument. A more serious objection is that symbolic logic is a bad approximation to the logic of ordinary language and thinking and in its present form would be more confusing than helpful in the sorting out of argument. There is much evidence to suggest that the logic of ordinary speech is in some cases three-valued, and it is known to be in some respects more similar to a modal logic than the Boolean or Russellian logic that Berkeley uses.

Non-Destructive Testing. By J. F. Hinsley. Macdonald and Evans, Ltd., 8, John Street, Bedford Row, London, W.C.1, 1959. Price 75s.

FOR many years there has been a need for a book such as this, which is written by the chief radiologist and physicist of Edgar Allen and Co., Ltd. His experience of the subject has been both practical and very varied, for during the 1939–46 period he was with the Aeronautical Inspection Directorate of the Ministry of Supply. One must admire the way in which he has marshalled his facts and the precision with which he has laid down the principles. Clearly the writing of this book took the author a long time and required very hard work. In the short foreword written by Dr. Edwin Gregory the point is made that although the demands of inspection were regarded as severe during World War II, inspectional requirements have become much more onerous, and in this "jet" and "atomic" age the older methods of inspection have been replaced or supplemented by techniques such as those described in this book.

Developments in inspection techniques have been so rapid in recent years that some details in any comprehensive treatise must appear out of date. Nevertheless this book will be of value for many years to come because it sets out in a readable manner the underlying principles: evaluated by someone with practical experience of radiography, physics and metallurgy in the service of designers, and users of metals. The two pages of name index and fourteen pages of subject index show the great width of the field covered.

Omissions there must be so perhaps one should not be surprised at the absence of reference to railway axles or to the lack of reference to the Non-Destructive Testing Group of the Institute of Physics. Considering the success and importance of non-destructive testing practised by the railways this section deserves some expansion in any future revision. Moreover, since testing must lead to executive action one should think in terms of more than the metal. For example, in practice if one tests the perfection of the paint or other corrosion prevention on a railway locomotive tender axle one need fear no fatigue crack: prevention is better than the discovery of the corrosion fatigue crack. But under the wheel seats the non-destructive testing is very valuable.

In the twenty chapters of this well written and illustrated book, some 495 pages in all, there is gathered much that will be of help in every engineering works. The inclusion of a table of Greek letters and their meanings is helpful for it is confusing that many such symbols are used in more than one sense: μ for example appears in the list with no less than seven meanings.

The first four chapters are fundamental, dealing with the language of the subject of defects and flaws, the obvious value of forms of testing, which do not cause valuable material to be scrapped, whether it is good or bad, by cutting it up to obtain sections for microscopy, or by drillings for chemical analysis. Chapters five to eight are concerned with X-rays, gamma-rays and the practice of radiological examination. The next three chapters consider ultrasonic testing, and the generation and detection of ultrasonic vibrations. Chapters twelve to fourteen describe the use of magnetic methods, and electrical methods of especial value in the detection of surface flaws. Three chapters then cover the sorting of mixed materials and a large group of miscellaneous methods, which even include the radiography of ancient monuments. A chapter on safety precautions in radiological laboratories is wisely included and the book concludes with chapters on the interpretation and presentation of test results, and mathematics and non-destructive testing. The appendices help to show the fields in which Cobalt 60, Iridium 192 and Thulium 170 are of the greatest help.

In all, this is a welcome, well written and very practical book.

Molecular Science and Molecular Engineering. By A. R. VON HIPPEL *et al.* The Technology Press of M.I.T. and John Wiley and Sons Inc., New York; Chapman and Hall, Ltd., 37, Essex Street, London, W.C.2. Price 148s.

THE title of this book suggests chemistry and chemical engineering, but in fact it deals mainly with molecular and solid-state physics, electronics and aspects of electrical engineering. This is the particular field of the Laboratory for Insulation Research in the Massachusetts Institute of Technology, of which Professor von Hippel is director. Many of the chapters are written by his colleagues there, although there are contributions from other departments of M.I.T., and from such places as the Bell Telephone Laboratories and the Westinghouse Electric Corporation. The main theme runs from atoms to molecules and the behaviour of charge carriers in gases, to the formation and structure of condensed systems, to dipoles and their spontaneous alignment in ferro-electrics and ferro-magnetics, and finally to the charge carriers in liquids and solids! In particular, ferro-electric and ferro-magnetic materials and devices are treated in some detail. Interspersed with the main theme are a few chapters on various aspects of chemistry, mainly concerned with materials such as synthetic polymers and ion-exchange resins. There are also, even more surprisingly, chapters on combustion and on the mechanisms of organic chemical reactions. The result is a mixture, rather than the intended synthesis, of information from various sciences.

Although it is intended for a very wide readership—"the professional scientist and engineer"—it is doubtful whether it will be of much value except to workers and potential workers in the fields covered by the main theme, and they will have to put up with a fair amount of material which is of relatively little importance to them. On the other hand, it is too specialised to be a satisfactory account of modern physics for the engineer who wishes to keep up-to-date with developments in basic science. It is a pity to have to criticise the work as a whole adversely, because many of the individual chapters are well written and excellently illustrated.

Books Received

Progress in Cryogenics, Vol. I. Edited by K. Mendelssohn. Heywood and Co., Ltd., Carlton House, Great Queen Street, London, W.C.2. Price 63s.

Handbuch der Kaltetechnik, Vol. 7. By W. Niebergall. Springer-Verlag, Berlin-Wilmersdorf, Heidelberger Platz 3, German Federal Republic. Price DM.96.

Operations Research—Methods and Problems. By M. Sasieni, A. Yaspan and L. Friedman. Chapman and Hall, Ltd., 37, Essex Street, London, W.C.2. Price 82s.

Seibt Export Directory of German Industries. Fourteenth edition. Edited by Dr. A. Seibt. M. Neven du Mont, 123, Pall Mall, London, S.W.1. Price 65s.

Guide to the Coalfields, 1959. Edited by R. H. Walkerdine. The Colliery Guardian Company, Ltd., 30 and 31, Furnival Street, London, E.C.4. Price 20s.

Modern Engineering Workshop Practice: Four Volumes. Editorial Consultant, W. A. Tuplin. Odhams Press, Ltd., Long Acre, London, W.C.2. Price 185s.

La Commande Electromagnetique et Electronique des Machines-Outils. By A. Fouille, J. Canuel and A. Peuteman. Dunod Editeur, 92, Rue Bonaparte, Paris (6e). Price F.3.4900

Progress in Nuclear Energy: Vol. 2, The Economics of Nuclear Power. Edited by I. R. Maxwell, P. W. Mummery and P. Sporn. Pergamon Press, Ltd., 4 and 5, Fitzroy Square, London, W.1. Price 105s.

Hyperstatic Structures: Vol. I, An Introduction to the Theory of Statically Indeterminate Structures. By J. A. L. Matheson. Butterworths Scientific Publications, 4 and 5, Bell Yard, London, W.C.2. Price 90s.

The Modern Diesel: Automotive Oil Engines for Transport, Marine and Industrial Use. Thirteenth edition. By D. H. Smith. Iliffe and Sons, Ltd., Dorset House, Stamford Street, London, S.E.1. Price 17s. 6d.

Proceedings of the 1958 *Atomic Energy Commission and Contractor Safety and Fire Protection Conference.* United States Atomic Energy Commission, Office of Technical Services, Department of Commerce, Washington, 25, D.C., U.S.A. Price 2.50 dollars.

The Engineer, Life and Diesel Engines

We print below extracts from the presidential address delivered by Mr. H. Desmond Carter before the Institution of Mechanical Engineers on Wednesday of last week, October 14. The parts of the address we have chosen to reprint relate to the development of exhaust pulse pressure charging and exhaust turbo-charging, to the relative values of gas turbine machinery, free-piston gasifier gas turbine installations, and the exhaust turbo-charged diesel engine and to the future development of two and four-cycle engines.*

EARLY in my career I was responsible for the design of a marine propulsion diesel engine, the first by my firm, and two-cycle as against the then long-established four-cycle stationary engine range. This engine was later developed for the stationary and locomotive fields. But the work for which I have been personally responsible and on which I wish to dwell concerns a later development of that engine, "exhaust pulse pressure charging" (E.P.P.C. for short). This process has enabled an increase of brake mean effective pressure of 30 per cent to be achieved and the speed to be more than doubled, thereby giving three times the power. Now much more recently exhaust turbo-charging has been adopted, which marries most happily with exhaust pulse pressure charging and a further 50 per cent increase in power on rated outputs has been attained (128 lb per square inch brake mean effective pressure, continuous rating) and greater increases are on the way. (I will not dwell on the development of the four-cycle engine and its pressure charging as this has taken place concurrently in many establishments and has been adequately described elsewhere.)

How did all this begin ?

Exhaust Pulse Pressure Charging

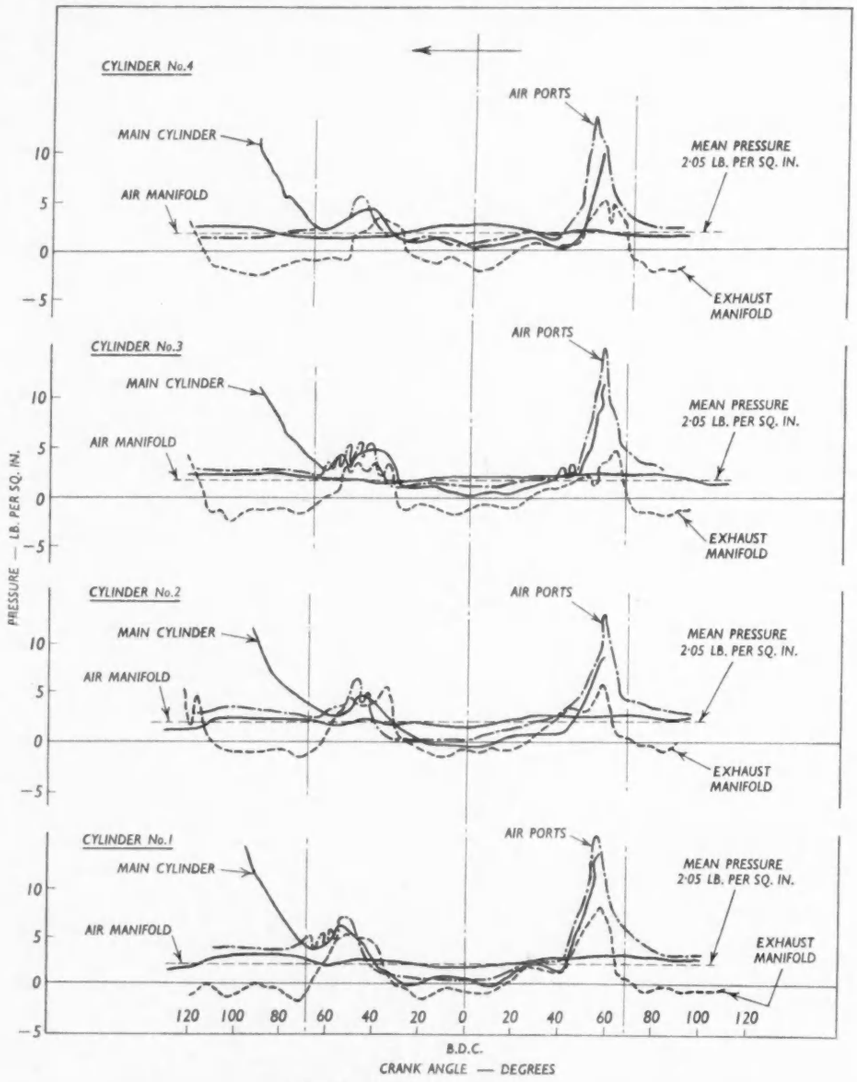
We go back to the time of the end of the second world war when the use of the cathode-ray oscillograph was still fairly new in industry. We used this technique to produce very accurate light-spring diagrams for studying the processes of exhausting, scavenging and charging in our two-cycle diesel engines of the port-controlled loop scavenge type. Laboriously we amassed a vast amount of data in the form of light-spring diagrams on a time base, for example, four groups of diagrams, each on a large blue-print, for a four-cylinder engine (Figs. 1 and 2).

At the time we began to become restive because we were merely amassing data without producing anything useful from it beyond a better understanding of what was going on inside our engines. This gradually led to a fierce determination to get something useful out of all this work and on my regular train journeys between Manchester and London I got into the way of studying these diagrams for hours on end with the above objective in view. Eventually, one could visualise vividly all that was going on inside the engine. There were substantial pressure fluctuations in the exhaust system, and indeed the work of Kadenacy, to which we were indebted, had already shown that periods of low pressure in the exhaust manifold could be used for improving the air flow through the engine cylinder, that is, for improving scavenging.

The positive pulses in the exhaust system, however, still had only a nuisance value and the whole idea in the past had been to suppress and minimise the effect of such pulses as far as possible. Study, however, led to the conception that this was wrong and that it would be a great thing if the positive pressure pulses could be tamed and harnessed to do something useful. This in turn led to taking the fundamental pressure pulse generated in the exhaust system on the discharge of exhaust gas from the engine cylinder and utilising this exhaust pulse to produce a pressure rise in the previous cylinder in sequence, towards the end of its scavenging period and just before exhaust-port closing. Ways were found of phasing the pulses correctly for this purpose and building them up in amplitude, and this in association with suitably proportioned exhaust branches, which were filled with surplus scavenge air towards the end of the scavenging cycle, completed the picture. In other words, the exhaust pulses pressure charged each cylinder in turn by returning excess air which had immediately previously flowed into the exhaust branches. This was a most exciting development and immediately produced results far in excess of any other single improvement of which we had had previous experience.

We now had an engine capable of extremely rapid breathing (as the pulses travel a little faster than the velocity of sound in the exhaust gas medium, say 1400ft per second), in which we synchronised periods of low pressure in the exhaust manifold with the scavenging part of the cycle to assist the air flow through the engine, and arranged the positive pulses of quite substantial magnitude to be phased to occur shortly before each cylinder had its ports closed by the upward-moving pistons. This extremely rapid alternation of positive and negative pressure gave us both good breathing and good charging, hence low scavenge air pressure but high trapped charge pressure, an ideal state of affairs.

The variables are firing order, angular spacing of the cranks, port timings, port areas, proportions of exhaust branches, exhaust manifold diameter and for scavenging



Pulses of same amplitude but badly phased.

Fig. 1—Cathode-ray oscillograph diagrams of a four-cylinder engine in an intermediate stage of development. Part of the cycle, exhausting, scavenging and charging, taken at each cylinder

* Chairman and Managing Director of Crossley Brothers, Ltd., Manchester.

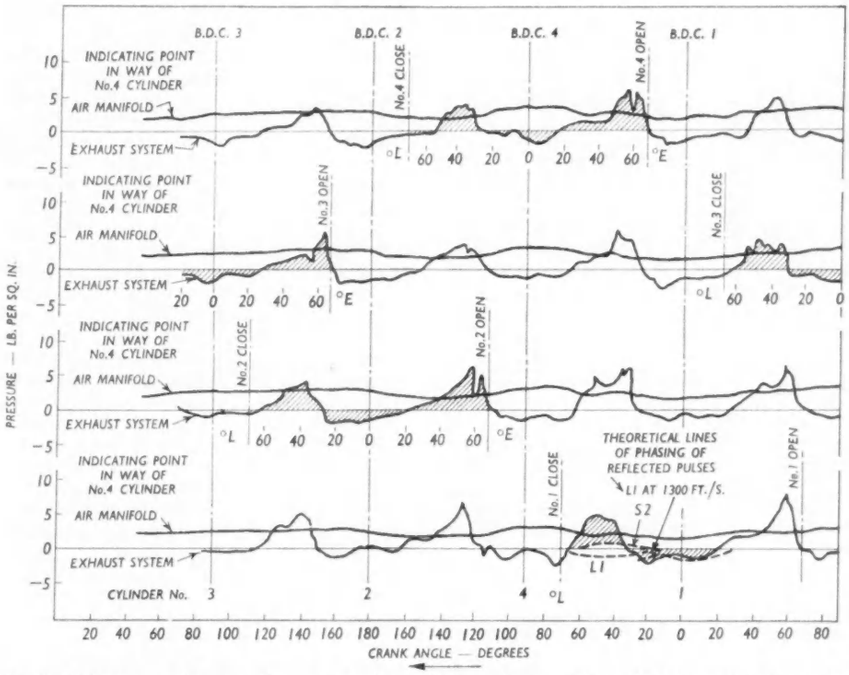


Fig. 2—Cathode-ray oscillograph diagrams of a four-cylinder engine in an intermediate stage of development. The complete cycle taken principally in the exhaust system

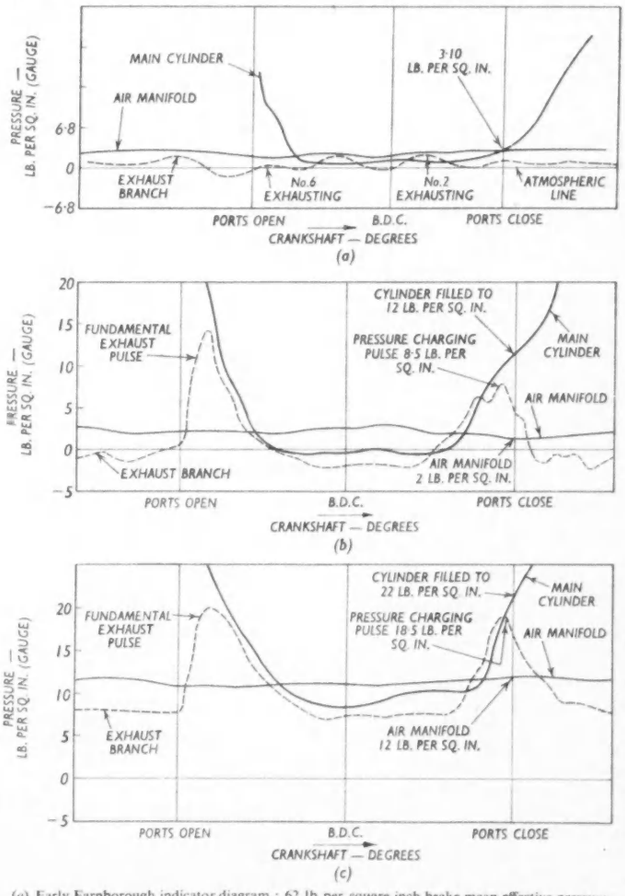
(not for E.P.P.C.), the length of the first few feet of exhaust primary pipe, used for open-ended reflection of the pulses with sign reversed. Thus, E.P.P.C. is independent of exhaust-pipe length. It is, however, dependent on the length of path from one cylinder to the next in sequence.

In the course of life, certain things are pleasant to look back upon and satisfying in retrospect. One of these in my case is the beneficial interaction of university type of engineering and research with practice in industry, and it gives me pleasure to acknowledge that this development was stimulated by Professor Mucklow's work (then in its earlier stages but later extended down the years by Professor Mucklow along with, in turn, several helpers) on the generation and propagation of pulses in pipes (wave action).

Fig. 3 (*a*) shows a typical light-spring diagram of two-cycle engines of an earlier type, and Fig. 3 (*b*) shows the later engines with exhaust pulse pressure charging. Such engines have been used in recent years for marine propulsion, for power generation in stationary work and in high-powered main-line locomotives.

Exhaust Turbo-Charging and E.P.P.C.

In modern form now the process of exhaust turbo-charging has been applied, as I have said, to these two-cycle engines with a consequent substantial further increase in specific output. This has been a most difficult but rewarding piece of work and it is fortunate that the process of exhaust pulse pressure charging can be combined with that of exhaust turbo-charging, the two being additive. Life is usually much more difficult than that. Nevertheless, nine years' development work was required before it was ready for use in the field. On the turbo-charged engine the positive pulses are still there and are in fact increased in energy content, but the base line from which they operate is merely raised bodily by the higher pressure levels produced by the exhaust turbo-charger ; this point is made clear in Fig. 3 (*c*). This diagram is grouped with Figs. 3 (*a*) and 3 (*b*) to show the three stages of development, naturally aspirated, exhaust pulse pressure charged and exhaust turbo-charged, that is, turbo-charging of the previous engine. On the three diagrams note the pressures of the trapped charge at port-closing of 2 lb, 12 lb and 22 lb per square inch respectively, corresponding air manifold pressures being 2½ lb, 2 lb and 12 lb per square inch. The attainment of 22 lb per square inch on the turbo-charged engine with an air manifold pressure of only 12 lb per square inch shows the effectiveness of E.P.P.C. under exhaust turbo-charged conditions. Without E.P.P.C. the pressure of the trapped charge would only have been about ½ lb per square inch above the air manifold pressure. The relevant figures are collected together in Table I :



(*a*) Early Farnborough indicator diagram ; 62 lb per square inch brake mean effective pressure at 300 r.p.m., 10½in bore, six-cylinder, 330 b.h.p. engine ; No. 6 cylinder. (*b*) Exhaust pulse pressure charging. Cathode-ray oscillograph diagram ; 80 lb per square inch brake mean effective pressure at 500 r.p.m., 10½in bore, three-cylinder, 350 b.h.p. engine: No. 1 cylinder. (*c*) Exhaust pulse pressure charging plus exhaust turbo-charging. Cathode-ray oscillograph diagram ; 120 lb per square inch brake mean effective pressure at 500 r.p.m., 10½in bore, three-cylinder, 530 b.h.p. engine ; No. 2 cylinder.

Fig. 3—Three stages in the development of two-cycle diesel engines

Table I

	Trapped charge, lb/in²	Pulse, lb/in²	Air manifold, lb/in²
Exhaust turbo-charged with exhaust pulse pressure charging	22	18½	12
Exhaust pulse pressure charged	12	8½	2
Original engine, no E.P.P.C. and no turbo-charging	3	1·0	2·5

The pressure differential of the trapped charge over the pulse arises from reflection of the pulse with unchanged sign from the top of the cylinder.

The system used includes a mechanically driven scavenge pump in series with the exhaust turbo-charger. This not only gives the highest output but also security in event of turbo-charger breakdown, as the engine will continue to run and give its full naturally aspirated power.

None of these developments has impaired the basic position of the port-controlled loop scavenge engine with E.P.P.C., namely that of providing a result of equal technical excellence with other forms of diesel power but by simpler means. If two engineering solutions are level in most respects, but the one is simpler mechanically than the other, then the simpler one is the better. It should require less maintenance, give longer runs between overhauls and cost less. No matter how well engineering equipment may be designed, sooner or later it will require overhauling and the fewer the parts the less the work, assuming equal degrees of skill in design and manufacture. This also agrees with Sir Ewart Smith's first requirement of a design, simplicity, as expounded in his Graham Clark Lecture. On the other hand, the four-cycle engine has benefited from a greater total research and development industry-wise, so many firms being on the job.

One of the most fascinating features of exhaust pulse pressure charging is that the application of this principle to an engine involves no additional mechanical complication. It is, therefore, a delightful subject with all the complication in the technique of development and in the final result the

engine is not encumbered with a single additional mechanical component.

Gas Turbines, Gas Generators and Diesel Engines

The reciprocating internal-combustion engine has now had a run of nearly 100 years and is currently being produced in vast numbers. Within its own useful power range it is predominant in most fields and even in the rightly jet-minded air it was, and probably still is, true to-day that most of the world's air transport is piston-engine propelled. What of the future ? It is certainly not without competitors. In the early days after the 1939–45 war the unique suitability of the gas turbine for the jet propulsion of aircraft became evident and vast strides have been made in that field, partly through British achievement. Names such as Whittle come to mind, also the "Viscount" and "Britannia" turbo-prop civil airliners and on to "Comets" and overseas aircraft with pure jet propulsion. At the time when these ideas were being investigated a wave of opinion swept through the world to the effect that for marine and land applications, as well as in the air, the gas turbine would predominate in comparatively few years. In other words, the poor old piston engine had "had it." This expectation has not been realised.

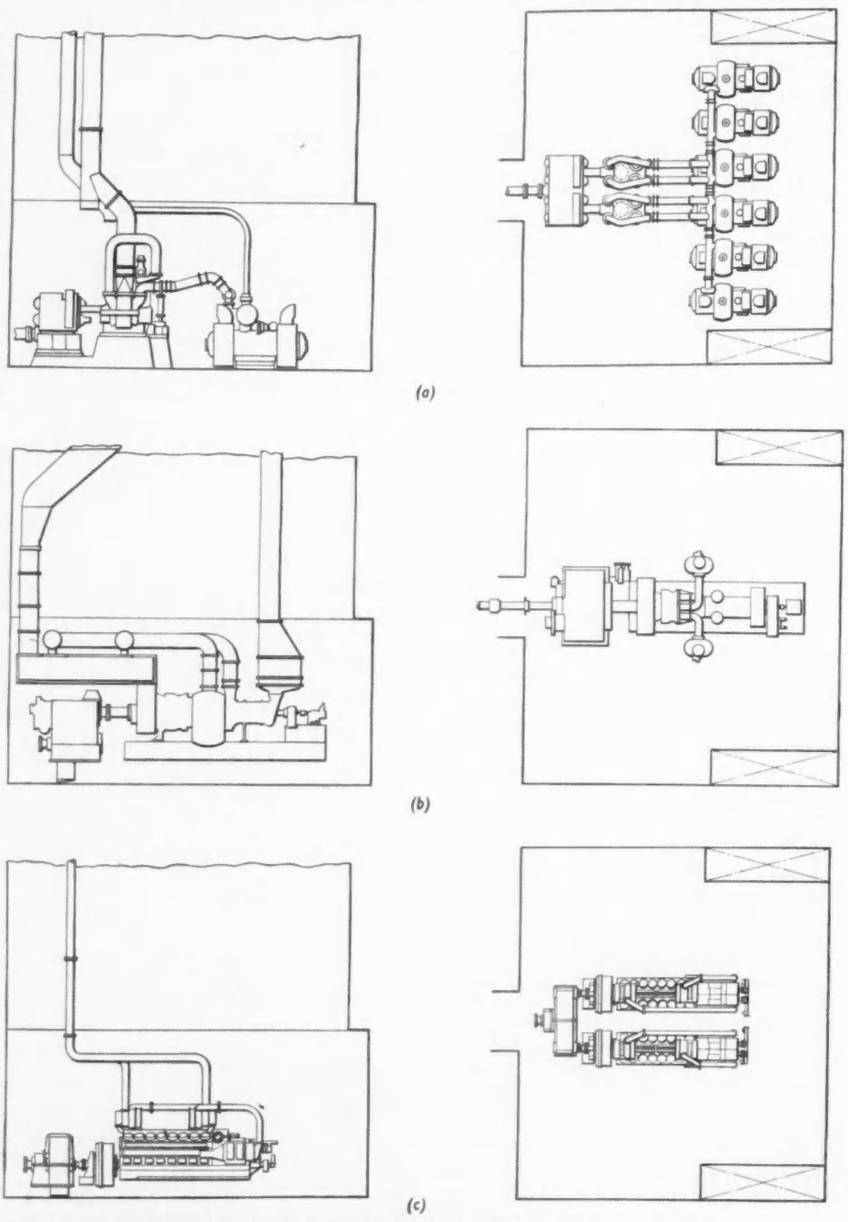
In the air the gas turbine promises to become supreme, both aeroplane and power units of this type revelling in high altitudes and speeds. Apart from the air the gas turbine has, during the last decade or so, found only limited fields of application for itself, although it is very useful in such fields, for example, in those oilfields where there is abundant natural gas and gas consumption does not matter ; for certain peak load sets, such as final emergency sets on the decks of ships ; fire pumps and generally in applications where fuel is cheap or where specific fuel consumption is unimportant ; where light weight and portability are assets and first cost is not a primary consideration. In practically all locomotive installations the gas turbine is unattractive owing to the very high fuel consumption arising from its even poorer part-load characteristic. In experimental cars promising road performances are marred by delay in response to the throttle (whilst the turbine is accelerating or decelerating), this being in marked contrast with the rapid response of the piston engine. On the sea the lower thermal efficiency and problems connected with the means of reversal count heavily against the gas turbine in merchant ships, although its light weight has attracted some attention for naval duties.

The reciprocating engine, chiefly as a diesel, continues to be the most efficient prime mover and best solution in most fields. Whether, by the use of cooled blades or ceramic or other heat-resisting materials, the gas turbine can be made to work at white heat with consequent improvement in thermal efficiency, instead of the current limitation of red heat, remains to be seen, and if successful this might alter the picture materially. As far as metals for dealing with these high temperatures are concerned, man appears to be nearing a limitation because of oxidation troubles and any further improvement in the performance of most metals at high temperatures by alloying can be but little more than marginal. The curves of the desirable physical properties all droop and run together at such elevated temperatures. The other approach of providing internal cooling passages within the blades has to contend with the difficulty that the blades are small and the passages tiny, hence specks of dust become significant and for such and other reasons progress with this development is disappointingly slow. High-temperature gas turbines with cooled blades have not been able to meet the tests of practicability, cost and reliability.

Free-piston gas generators represent another fascinating development, with the big advantage that multiple units can be strung together merely by piping to drive a single turbine of relatively high power. On the other hand, this high-temperature piping, festoons of it, is quite an item and a problem. The function of the reciprocating gas generator is to provide the huge volumes of hot gas for which the gas turbine has such a voracious appetite. The gas generator is inherently a bulky, clumsy method of achieving this as it does so by reciprocating as distinct from rotary means. Thus, the free-piston gas generator with a 13in diameter diesel cylinder requires compressor pistons of 35in diameter, and a series of these separate generators, therefore provides a relatively bulky (except in comparison with large slow-speed engines) and expensive installation. The reciprocating gas generator does, however, enable use to be made of a cycle with a high maximum temperature with consequent improvement (relative to the rotary gas turbine) in fuel consumption.

Questing for a less bulky form leads to the passing thought that as against this an alternative type of gas generator, comprising a high-pressure diesel engine with compact normal cylinder centres (but used as a gas generator) in, say, a six-cylinder in-line unit, would provide by comparison a very compact unit in suitable combination with the inherently compact aerodynamic (centrifugal or axial) compressor.

This, however, in turn leads to the consideration that fundamentally one is dealing with three main elements, namely, the reciprocator (diesel engine), the compressor (rotating or reciprocating) and the gas turbine. Two of these elements are used in combination in a free-running unit feeding the third, which is used for providing useful power. Thus, the free-running unit develop-



(*a*) Views in elevation and plan of a typical gas-generator turbine installation.
(*b*) Gas turbine with heat exchangers and intercoolers.
(*c*) Twin-geared two-cycle diesel installation, turbo-charged, driving through fluid couplings and gears on to a single propeller-shaft.

Fig. 4—Three alternative marine power units of 6000 s.h.p. All shown to the same scale

ing no external work, can be rotating as in the exhaust turbo-charger of the conventional diesel engine or reciprocating as in the free-piston gas-generator power plant. It is a question of which combination is the more effective. In the one case the useful power unit is the diesel engine and in the other the gas turbine. Viewed in this light, the turbo-charged diesel power unit has two advantages. First, it has the compact rotary free-running unit (axial-flow turbine with centrifugal compressor) as against the bulky reciprocating free-piston gas generator, and, secondly, the provision of useful power by the diesel engine at acceptable revolutions per minute for driven machinery without the interposition (as required by the gas turbine) of a gearbox with a large ratio of reduction in speed—a costly and bulky unit. The turbine in the free-piston gas-generator power unit rotates at many thousands of revolutions per minute and is quite unsuitable for direct-coupling to an electrical generator or ship's propeller. In other words, the free-piston power plant, in addition to the bulky reciprocating gas generator, requires the use of an additional component, namely, the above-mentioned large-ratio reduction gearbox, for example, 70/1, transmitting relatively large power. Further, the free-piston gas generator is at a substantial disadvantage in thermal loading of the diesel part of the equipment, in the relatively complicated control gear, the automatic regulation of inner and outer dead centres of the free pistons as load and speed of the turbine vary, in part-load fuel consumption and in combustion efficiency arising from the variable inner dead centres. It would thus appear that from the point of view of general attractiveness, the simplest engineering solution, compact dimensions, flexibility and ease of control, thermal efficiency, reliability and competitive price, the conventional highly turbo-charged diesel engine in modern form has the advantage.

A comparison of three alternative power units of 6000 s.h.p. for ships' propulsion is shown in Figs. 4(*a*), 4(*b*) and 4(*c*), all to the same scale. These are all of the heavy-duty type suitable for merchant marine application. The first, in Fig. 4(*a*), covers the gas generator-cum-turbine installation in the "William Patterson"; the second, in Fig. 4(*b*), the purely rotary gas turbine installation in the "John Sergeant." In order to achieve reasonable fuel economy, this gas turbine installation is complete with heat exchangers and intercoolers which greatly increase the bulk and weight of the installation, but even then the fuel economy is only of the order of 0·52 lb per shaft horsepower per hour, as against 0·375 lb per shaft horsepower per hour for the diesel engine. It is, of course, possible to produce very light-weight gas turbine units without heat exchangers, and this is more usual, but the fuel economy is then poor, over 1 lb per shaft horsepower per hour. The third power unit* in this comparison, Fig. 4(*c*), is a diesel installation of moderately high output avoiding extremes. Thus, the piston speed is 1350ft per minute and the brake mean effective pressure 115 lb per square inch, but a two-cycle engine and therefore equivalent to 230 lb per square inch on a four-cycle engine, the cylinder bore being 10½in. The power aggregate consists of two sixteen-cylinder vee-type diesel engines, exhaust turbo-charged, of

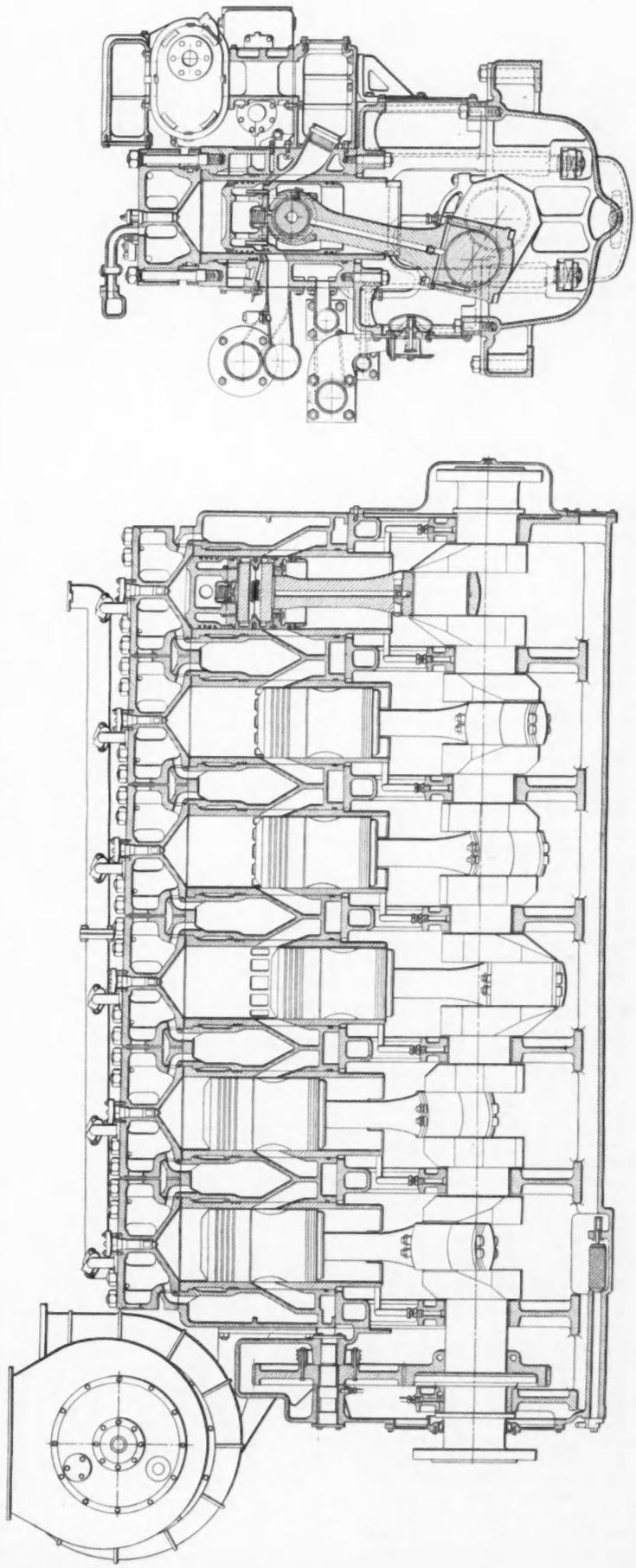


Fig. 5—High-pressure two-cycle engine with port-controlled loop scavenge, exhaust pulse pressure charged plus exhaust turbo-charging

* The type of diesel engine with which I am dealing gives me no choice but to concentrate on the engine with which I have been associated. Even if one ranges beyond the exhaust pulse pressure-charged two-cycle engine on to the general port-controlled loop scavenge type there are substantially no other British designs and only four or five (some very good ones) beyond these shores in the power range covered, but several (overseas designs again) in a rather different class of engine, the large slow-speed marine diesel, crosshead type, of several thousand horsepower.

3200 b.h.p. each, direct-reversing and coupled through hydraulic couplings and gearing on to a single propeller shaft, the engines running at 600 r.p.m.

It will be seen that the diesel unit compares favourably in dimensions with the other two forms of power unit. Brief particulars are given in Table II :

TABLE II

	Gas generator	Gas turbine power unit	Geared twin diesel power unit
Weight, lb/s.h.p. ...	35	55	31 (26 without fluid couplings)
Fuel consumption, lb s.h.p./hour	0·44	0·52	0·375
Overall length	39 ft	41ft 6in	35ft (30ft without fluid couplings)

NOTE.—A comparison with modern slow-speed direct-coupled diesel engines, exhaust turbo-charged, running at about 115 r.p.m. gives a weight per shaft horsepower of 90 lb to 120 lb a length of 34ft to 39ft, and a much greater height, 25ft to 32ft.

TWO- AND FOUR-CYCLE ENGINES IN THE FUTURE

Now a word about two- and four-cycle engines, as the conventional turbo-charged diesel engine can take either form. Both types are in process of rapid development in the direction of greater specific outputs. They are heading in the next decade for commercial ratings of about 300 lb per square inch brake mean effective pressure, with current figures rarely exceeding 160 for the four-cycle and 120 for the two-cycle engine. It is a hard-fought fight and no doubt there will be room for both types, but the two-cycle engine would appear to have further scope for development from its present position, and later on if 300 lb per square inch brake mean effective pressure is attained this is, of course, equivalent to 600 lb per square inch brake mean effective pressure on the four-cycle engine. Already in research on uniflow poppet-valve two-cycle engines outputs of the order of 200 lb per square inch brake mean effective pressure have been attained, and the port-controlled trunk piston two-cycle engine, more difficult to develop, will no doubt soon follow, whereas four-cycle engines are currently recording 300 lb per square inch brake mean effective pressure in the engineering laboratory. High levels of exhaust turbo-charging on either cycle involve the acceptance of higher cycle pressures, including higher maximum cylinder pressures such as 1500 lb to 2000 lb per square inch. Hence the emergence of the high-pressure engine of which Fig. 5 is an example, being a port-controlled two-cycle engine of the general type previously described.

On two-cycle engines the temperature in way of the top piston ring is a problem at very high outputs but can probably be accommodated by future development ; it is more severe than on the four-cycle engine but less than on the free-piston gas generator, on account of the high temperature of the uncooled air delivered under substantial pressure from the reciprocating compressor and which is necessary for the best efficiency of the gas turbine part of the equipment. It is a pity that the inherent elegance of the gas-generator power plant for dealing with the first part of the cycle is marred by various disadvantages. It has a simple heat balance, the function of the gas generator being that of supplying hot gas to the turbine and hence anything, such as intensive cooling, which abstracts heat from the gas, detracts from the performance. On the other hand, the converse is true of the highly turbo-charged diesel engine, where the more cooled the air delivered the better are the results.

Further, the two-cycle turbo-charged diesel engine currently has exhaust temperatures in the region of only 900 deg. Fah. whereas the turbo-charged four-cycle engine is already having to take measures to stop the temperature of the exhaust gases from rising above 1200 deg. Fah., above which temperature the most expensive turbine blade materials are necessary, and the problem of fouling of the turbine blades by vanadium pentoxide arises if anything but the highest grade fuels are used. Thus there is considerable scope for boosting up the output of the two-cycle turbo-charged diesel engine before high-temperature problems of the exhaust turbine arise.

Hydrostatic Transmission Design

Recent years have seen a revived interest in hydrostatic transmissions, and an application particularly canvassed has been tractors on which it is often not possible to change gear when moving. Joseph Lucas (Hydraulic and Combustion Equipment), Ltd., having a highly developed fuel pump design, has evolved motors and control gear to adapt it to the transmission application.

IN recent years a revived interest in hydrostatic transmissions for applications involving infinitely variable drives has been observed. One of the pioneer projects in this renaissance was the agricultural tractor built by the National Institute of Agricultural Engineering, intended to draw farm implements at closely stipulated speeds—for instance, a potato harvester must travel just fast enough, perhaps 2 m.p.h., to keep the sorting crew occupied. Many other applications exist, particularly in industrial usage where a machine may often be moved forward and backward against heavy resistance at frequent intervals, and to encompass these various requirements, Joseph Lucas (Hydraulic and Combustion Equipment), Ltd., has evolved a variety both of hydraulic circuit designs and of motors, rotary and stationary, and control gear.

One refinement of the original N.I.A.E. system is a device to reproduce the behaviour of a limited-slip rather than a full differential. This is in principle quite simple : the flow through each motor is monitored by including orifices in the circuit—since it is desired to detect only coarse differences, slight restrictions involving only small losses are adequate—and a valve regulating the flows moves to equalise the pressure drops. The construction of the valve is seen in Fig. 1 ; the flow to each motor passes through one of the adjustable restrictors and then enters one end of the spring-centred plunger through a flow-smoothing grid. If the pressures on the two sides of the plunger are different, the plunger moves against its centring springs, and at the low-pressure end the orifices in the plunger cease to register completely with the delivery annulus surrounding them. The plunger will come to rest when the greater pressure drop through the orifice passing more oil is balanced by the more than proportionately increased pressure difference through the ports, plus the spring load of 3 lb on a $\frac{3}{4}$in diameter valve ; thus the higher flow is delivered at a markedly lower pressure. Clearly, different pressure drops cannot be sustained for equal flows, so the device is not a flow equaliser, nor is such desired since it would be equivalent to connecting the two motors mechanically or hydraulically in series.

A series connection of the motors is, however, an advantage in certain applications although in its simplest form it acts as a differential lock. The size of pump needed is determined by the maximum swashplate angle attainable and the maximum motor speed desired. If two motors are connected in parallel for "low gear" work and in series for high output speeds, the size and, hence, cost of the pump can be reduced, although at a small cost in increased leakage and friction losses in the upstream motor. The change from parallel to series is, of course, a departure from the infinitely variable behaviour associated with hydrostatic systems, but the system would normally be designed so that the speed at which the maximum tolerable pressure was needed in the series case was well below the maximum speed in the parallel mode, so that changes from one to the other would not be oppressively frequent. (At full input power, the pressure at which the relief valves lift is

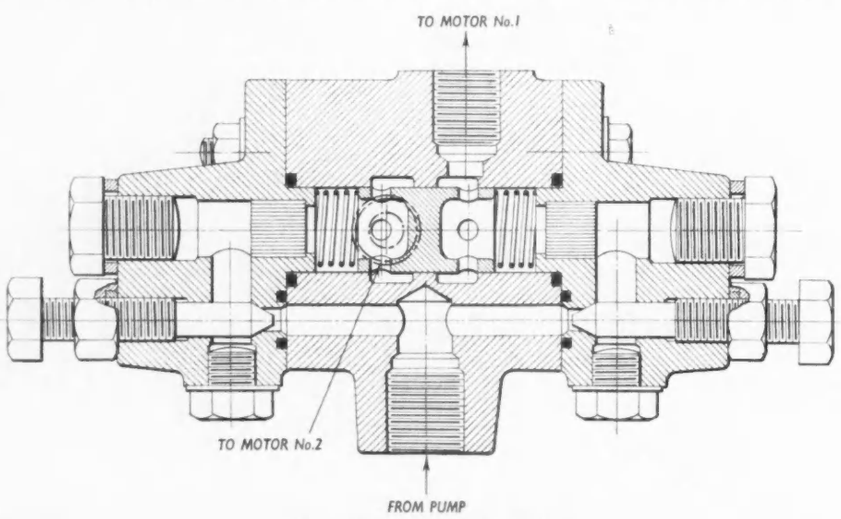


Fig. 1—Section through flow divider

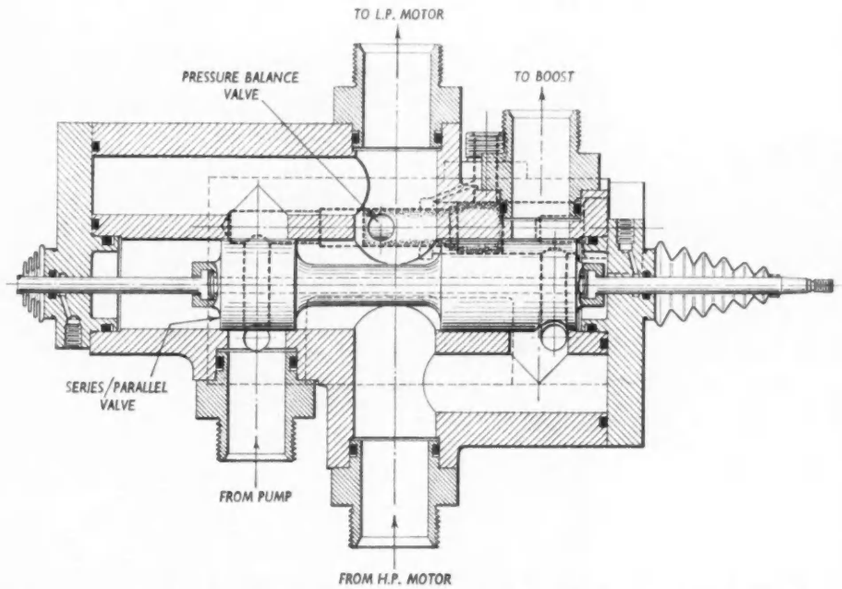


Fig. 2—Series/parallel valve, incorporating pressure balance valve to allow different motor speeds, seen in the series position

normally attained at a swashplate angle approximately 30 per cent of full deflection.)

Some provision must be made for differential wheel movement in series operation. This is done by detecting any difference in the pressure drops across the motors, and by-passing oil round the one sustaining the higher torque. The sensing element is a compound piston, with one diameter $\sqrt{2}$ greater than the other, sliding in two precisely coaxial bores ; thus the piston is in balance when the pressure drop between one end and the central annulus is twice that between the other end and the annulus. This is the condition in which the upstream and downstream motors are desired to run relative to boost pressure, and when it does not pertain a bleed is opened either from full to intermediate pressure or from intermediate to boost pressure. The proposed design for this device incorporates it in the series/parallel changeover valve, as shown in Fig. 2. In the series mode illustrated, the pressure balance valve moves to the right if the intermediate pressure is too low, thus uncovering a drilling in the small bore which leads to the input to the downstream motor, i.e. the intermediate pressure gallery. If the intermediate pressure is too high the valve bobbin moves to the left, and the large end uncovers a drilling leading by an external union to boost pressure. Since the differential valve has only small passages, any large difference in speed between the two motors will result in the faster-running unit being supplied at lower pressure. When parallel operation is selected, the valve moves to the right hard against its stop, but no flow passes through it ; note that the differential limiter cannot be included in this circuit, since it would restrict the flow when series was selected. When the swashplate moves through zero into reverse during parallel operation, the valve moves full left and seats on the collar at the change in radius, and again no flow passes. The valve malfunctions, however, in reverse in the series case; if the intermediate pressure is above the mean of high and boost, intermediate is connected directly to the pump through the external piping, and if pressure in the intermediate ports is low it is lowered still further by a bleed to boost opening. Thus, at least at low speeds, markedly unequal braking or reversing efforts must be expected in the series mode.

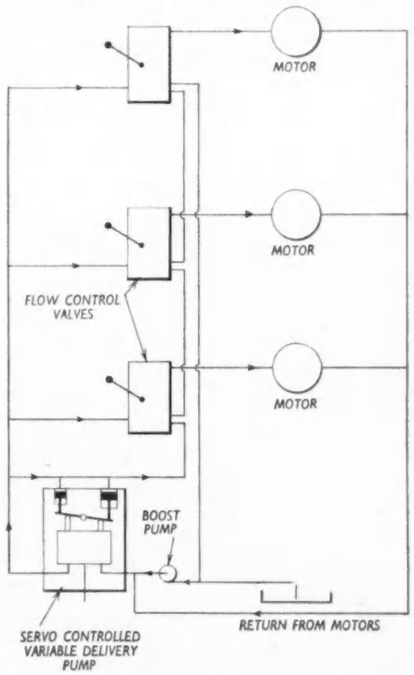


Fig. 3—Diagrammatic layout for single pump multi-circuit system

The Hydraulic and Combustion Equipment division is also aware of the undesirable practice prevalent, particularly on vehicles, of using separate pumps for each service. To remedy this, a system of automatic control of swashplate angle has been proposed, and is illustrated diagrammatically in Fig. 3. A single pump supplies a number of control valves in parallel, and all the valves are connected in series in the output control circuit, so that if one or more of the valves demands more oil the pump output is increased. The diagram shows that the turning moment on the swashplate is highly dependent on the pump output pressure, and since the reaction of the plungers on the plate is also a function of the pressure difference across the pump, the output pressure will vary widely. The control valves other than the one calling for increased pressure must, therefore, have some means of suppressing the tendency for their output to increase, and this takes the form of a pressure drop limiter rather like that described for use in the tractor with parallel motors ; in this case it merely acts to minimise the change in pressure across the variable orifice. Thus, the tendency for one motor to speed up when another is stalled is lessened.

The construction of the proposed flow control valve is shown in Fig. 4. Control valve *A* is manually operated and is a conventional spool valve notable only for a sealing face very narrow in the direction of pressure drop. The pressure differential across this valve is applied to the servo valve *B* ; at a difference of 30 lb per square inch the valve opens. The pressure upstream of valve *A* is also applied to the outer ends of the unbalanced main flow valve *C*, and when the pressure drop through *A* reaches 32 lb per square inch, the valve *C* begins to move to the right and restrict the outlet; the spring opposing the valve is very long when uncompressed, and an increase in differential to $40\frac{1}{2}$ lb per square inch suffices to close it. (In this case the difference exists across valve *C* and there is no flow through valve *A*.) It will be noticed that the control valve functions as an excess flow shut-down valve, giving protection against hose rupture, in which case it can be reset simply by closing the manual valve *A*.

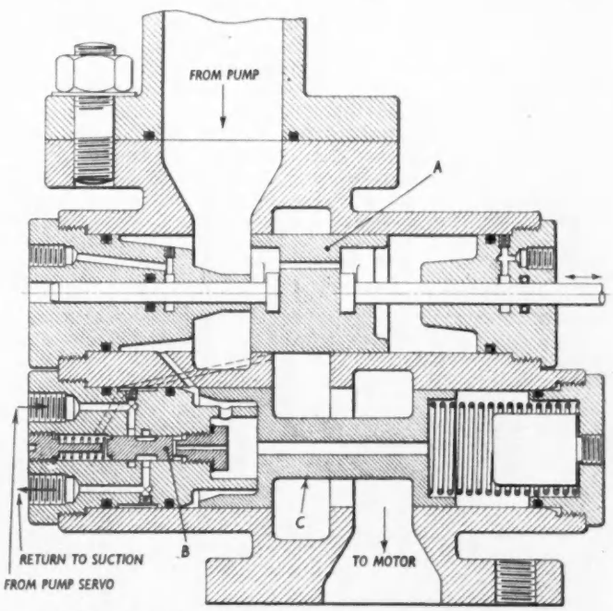
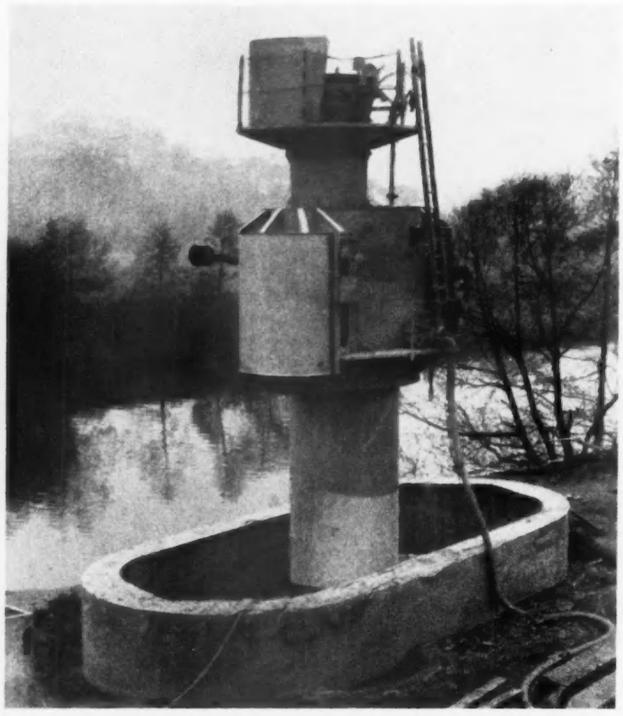


Fig. 4—Flow control valve for single pump multi-unit circuits

It will be observed that the system controls, in fact, pressure drops rather than flows, and, hence, is liable to be affected by changes in oil viscosity, but this is considered not to be a difficulty.

Caisson Sinking At Queenhill Bridge

The Queenhill bridge over the River Severn has been under construction for just over a year, as part of the Ross Spur motorway scheme. The entire scheme comprises 20 miles of dual 24ft carriageway built to motorway standards roughly between Tewkesbury and Ross. Here, we are concerned principally with the foundation work for the bridge ; a caisson for one of the main piers is shown on the right.



ONE of the principal constructional tasks involved in building the Ross Spur Motorway is the bridge crossing the River Severn at Queenhill. At the eastern end of this motorway scheme, a three mile length of road is being built under one contract, which includes the Queenhill bridge, which is half a mile long, 850ft of viaducts, three subsidiary bridges and two underpasses.

The Queenhill bridge has a central span of 237ft 6in between main piers and two side spans each of 131ft 3in. These main spans are to be of riveted structural steel, flanked on each side by an anchor span of 84ft 8in in reinforced concrete, followed by fourteen approach spans on the east side and eight spans on the west, each 81ft 8in in length and of reinforced concrete. The two carriageways are almost entirely separate between the bridge abutments, and each carriageway structure has its own set of caissons, its own steelwork and its own concrete spans. The bridge consists of a succession of cantilever and suspended spans. Two reinforced concrete anchor piers form a break between the steel superstructure and the reinforced concrete of the approach spans. The bridge is curved along its entire length, the radius of curvature being approximately 8000ft.

A substantial amount of excavation for pier foundations has been carried out since work was started on the project in June, 1958. The country rock underlying the clays and sandy gravels of the river flood plain is a soft red decomposed marl and foundations for fifty-two piers are being constructed in caissons which are being sunk under compressed air. There are also two caissons for foundations for the east abutment. In some cases, over 30ft of sinking is required before a sufficiently fresh marlstone is sunk.

Construction of approach spans. In the background is the massive rail-mounted shuttering assembly which enables an entire span to be built at one set-up

Four types of caissons are being sunk. For the east abutment, the caissons are rectangular and measure 24ft by 18ft 6in ; the approach span caissons are circular and are 16ft in diameter at the base ; the anchor piers and main span piers are rectangular in plan with semi-circular ends, measuring 25ft by 15ft and 31ft by 13ft 6in respectively. The foundations are hollow, with a 3ft thick external wall and two 2ft thick cross members. On completion to the required depth, they are sealed with a 6ft cap of reinforced concrete.

The anchor pier, main pier, and east abutment caissons have vertical sides and are encased in steel for the lower 16ft. The approach span caissons have steel skins throughout their height, and after the bottom 12ft, which is of 16ft diameter, taper into a diameter of 10ft, which continues up to ground level.

Forty-four approach span caissons are to be sunk, forming the bulk of the caisson work. A 16ft diameter shoe 12ft high in $\frac{1}{4}$in mild steel plate is first fabricated on the surface. The working chamber is formed by a cone of mild steel plate tapering up from the cutting edge to a central 6ft diameter shaft. On completion, this section of the caisson is pitched, surveyed into position and sunk under free air through the first layers of gravel and clay. The open chamber formed by the top of the conical working chamber and the wall of the cutting shoe is then filled with mass concrete to within 12in of the top. An 8ft high taper in $\frac{1}{4}$in thick mild steel plate is then welded in position, reducing the external diameter of the shoe to 10ft. Shutters are then placed above the top of this cone to form the shaft wall, and concrete is poured. A grab, fitted with an orange peel bucket, is used to excavate through the gravel, after which excavation is by clay spades and hand loading into skips. Shuttering is erected in 4ft rings at the surface as required and as

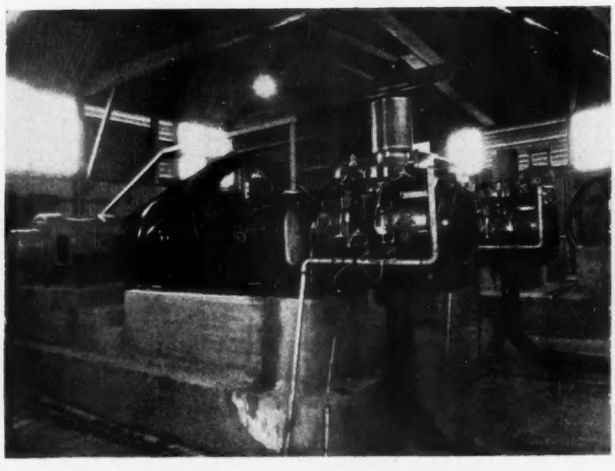
the ground below is excavated, the shoe moves down, carrying with it the 10ft diameter foundation of 2ft thick circular reinforced concrete wall.

The figure-of-eight or vertical air locks, which are fitted at the top of the mild steel shafts, comprise a vertical cylinder flanked by two small chambers, with airtight doors dividing them from the main compartment. This compartment also has a balanced trap door which opens downwards to the shaft and a circular lid at the top end, fitted with a packing gland to allow the passage of the hoisting rope. The shafting to which the lock chamber is fitted is not circular but more nearly egg-shaped, containing a circular muck shaft and a smaller, semi-circular man shaft. Hoisting in the shaft is effected by a 22 RB crane fitted with long and wide tracks and power-controlled hoisting and lowering. Signalling is by bell and flashing light in the operator's cabin.

The hoisting procedure under pressure consists of raising the skip through the open flap door at the base of the air lock, closing the flap, releasing the compressed air in the chamber and raising the skip, the top circular lid being carried up as the skip is hoisted clear in free air. In lowering, the skip and lid are returned to the chamber, and the lid is held firmly in position by clamps. These clamps are arranged so that air cannot be admitted to the lock until they are secured. The air pressure in the lock is brought up to the same level as the air in the shaft, the lower flaps are opened and the lowering continues. The air pressure is kept at 2 lb per square inch above the hydrostatic head.

The massive shutter used for forming each span is shown in the illustration opposite. This is curved on the 8000ft radius of the bridge and carries the 500 cubic yards of concrete required for each span. It is carried on two sets of rails and is independent of the piers. To support this weight, the track is in turn carried on some fifty piles for each length of shutter. Batching plant arrangements include two plants of 1 cubic yard capacity on the east bank and two further plants of 1 yard by ½ yard capacity on the west bank.

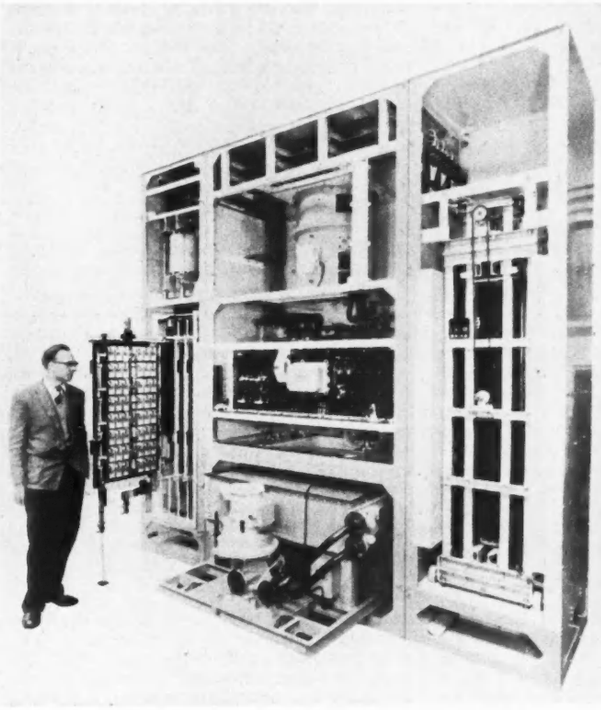
The agent authority acting for the Ministry of Transport and Civil Aviation for this section of the motorway is the Worcestershire County Council (County Surveyor, Mr. W. R. Thomson, M.I.C.E., M.I.Mun.E.). The consulting engineers for the bridge are Sir Alexander Gibb and Partners. The contractor is A. E. Farr Ltd.



Compressors supplying low-pressure air for the caissons at Queenhill Bridge

Germanium Rectifiers for Marine Use

TWO germanium rectifiers, each rated at 255kW, 225V, 1136A have been supplied to the Admiralty by the heavy plant division of Associated Electrical Industries, Ltd., Rugby, for installation in H.M.S. "Mull of Kintyre," a maintenance ship with 440V, three-phase, 60 c/s main supply system. The rectifiers will be used for supplying d.c. power to other ships lying alongside. This installation is believed to be the first large semiconductor equipment for use on board ship.



255kW semiconductor rectifier cubicle with covers removed to show (left), rectifier trays ; (centre) transformer with fan above, and air cooler ; and (right) voltage regulator

Each 255kW rectifier is a self-contained unit complete with forced-air-cooled germanium rectifier cells, rectifier transformer, automatic voltage regulator, fan, air cooler, sea-water pump, and all auxiliary relays, starters and fuses. All these components are housed in a steel-framed, aluminium alloy cubicle, the only external electrical connections being the main 440V, three-phase a.c. input, the d.c. output, and two remote warning circuits. One complete unit is illustrated here with all the front covers removed : the left-hand cubicle section contains the rectifier cells mounted on three trays, one of which is shown withdrawn from the cubicle for inspection. The central section houses the rectifier transformer with the fan above it and the air cooler unit below it, and the right-hand section houses the voltage regulator. All the auxiliary relays, starters, and fuses are grouped together in the centre cubicle section, with access through hinged covers.

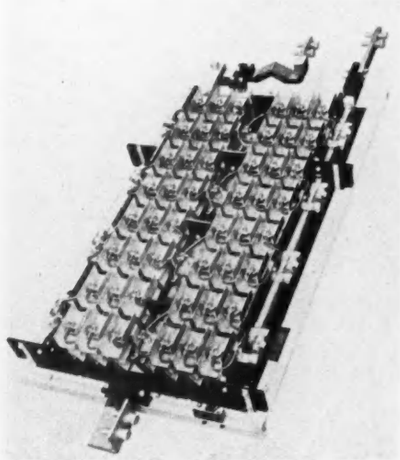
For ease of transport and installation the cubicles were built in three sections which are bolted together when installed. The two 255kW units face each other and the whole installation, including the space between the cubicles for withdrawing components, occupies a space of approximately 11ft cube.

All the equipment was built to Admiralty requirements for withstanding shock and vibration, by adapting A.E.I. standard industrial designs of rectifier trays, carrying solidly mounted germanium rectifier cells and their cooling fins, to meet these conditions. One of the rectifier trays is illustrated below. The rectifier cells (type GPC) are connected in series and parallel in a three-phase bridge connection.

Elsewhere in the equipment, use has been made of existing designs of Admiralty-approved electrical components such as the stepless voltage regulator, the fan and pump motors, and the motor starters.

As the rectifier operates in ambient temperatures up to 50 deg. Cent., closed-air-circuit cooling is used, the air being passed through an air-to-sea-water heat exchanger in the lower part of the central section. This air cooler and its water pump, pump motor, and water flow failure alarm relay form a compact assembly which can be withdrawn on rollers from the cubicle for maintenance, as shown in our first illustration. Air flow is downwards through the central cubicle section and upwards through the two outer sections.

If there is any interruption in the cooling water supply, the rectifier can be changed over to open-air-circuit cooling, without taking the rectifier off load, by opening hinged covers at the end and front of the cubicle. In this condition, and with the fan running normally, the rectifier can be operated at its full rating if the ambient temperature does not exceed 35 deg.



Rectifier tray showing arrangement of GPC germanium cells and fuses

Cent. or at reduced loads for ambient temperatures up to 50 deg. Cent. There is no lower limit of air temperature when operating semiconductor rectifiers.

The rectifier is required to give a d.c. output of 225V ± 2 per cent at any load and over the range of a.c. supply voltage fluctuations. This voltage control is obtained automatically by the use of a d.c. voltage relay which is connected across the d.c. output terminals and controls a pair of reversing contactors in the supply to the driving motor of the stepless voltage regulator. This regulator is a delta-connected auto-transformer with moving contacts. The output of the voltage regulator is connected to the primary of a buck-and-boost transformer, the secondary of which is connected in series with the secondary output of the main rectifier transformer, to raise or lower the a.c. voltage applied to the rectifier and consequently raise or lower the d.c. output voltage.

As the fan and pump motors are connected to the incoming supply the rectifier is ready to be put on load immediately the 440V a.c. supply circuit-breaker is closed.

The overload rating of the rectifier is 25 per cent for five minutes or 100 per cent for five seconds, and the overall efficiency at full load, calculated from a summation of losses is 92·8 per cent.

The d.c. output is taken to a main distribution board, and the fuses on this board protect the rectifier in the event of faults on any outgoing d.c. feeder. Internal faults, other than rectifier cell failure or faults on individually fused auxiliary circuits, are cleared by the a.c. supply circuit-breaker. For protection against the failure of rectifier cells, fuses are connected in series with the rectifier cells, one per pair of parallel paths, to isolate a faulty group of cells. The condition of these cell fuses is shown by indicating lamps on the front of the cubicle. If a blown fuse is indicated, the rectifier can be left on load and the fault investigated later when it is convenient to switch off and isolate the equipment.

Indication of air flow or water flow failure is given by diaphragm pressure-switch relays.

Some of the requirements, such as resistance to shock and the inclusion of an air cooler and sea-water pump inside the cubicle, are peculiar to the Admiralty and would not often be required in a merchant ship. Closed air circuit cooling is always easily available in suitable cases, but the manufacturer points out that corrosion need not be a problem, for the rectifier cells are completely sealed and the protection of other components and cubicle metal work can be dealt with as for other marine equipment.

Both germanium and silicon rectifiers, either forced cooled, air cooled, or naturally cooled, offer possibilities for marine use mainly because of the flexibility of layout and rating obtainable for particular applications.

Standard rectifier cells can be connected in series and parallel to give a wide range of d.c. voltage or current ratings up to power ratings of several hundred kilowatts from a single cubicle.

For most marine applications, automatic voltage control should not be necessary unless there are wide variations in a.c. supply voltage. The d.c. regulation from full load to light load of a three-phase bridge-connected germanium or silicon rectifier is usually about 10 per cent, but if a closer regulation is required, it can be reduced to about 6 per cent by using the rectifier cells below their full rating, thus enabling the transformer impedance, which is used for fault current limitation, to be reduced.

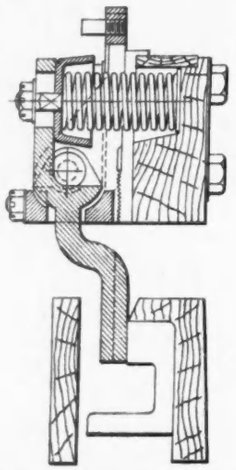
Third-Rail Traction at 1200V

IN the revision of British Railways electrification plans in 1956 it was intended that the Manchester-Bury electrification of the London Midland Region should be converted from its 1200V d.c. system to high-voltage a.c. at 50 c/s. This line is unique on British Railways in having a third-rail supply with side-contact collection, and the new electrification programme afforded an opportunity to bring the section into conformity with others. The need to modernise the Manchester-Bury rolling stock, however, was pressing, and therefore it was later decided to build new trains for the existing system rather than to postpone improvements until the electrical, civil engineering, signalling and other works required for conversion to standard-frequency a.c. could be carried out.

Trains of the new rolling stock are now entering service. They comprise twenty-six two-car sets which are being built at the British Railways (London Midland Region) Wolverton Works. A set consists of a motor open second brake and a driving trailer composite. Normally the sets are coupled in pairs to form four-coach trains, but they may operate singly in off-peak hours. The coach bodies are of welded steel construction and are carried on welded mild steel underframes of standard British Railways design. As seen in one of the accompanying illustrations, a profile new to British Railways electric stock has been adopted for the driving cabs, with the object of providing better vision for the motorman and improving the exterior appearance of the trains.

The drawing and the second illustration show the shoegear and supply system. It will be seen that the flat collector shoe is pivoted and is spring-loaded to bear inwards against a face of the special side-contact conductor rail, which is laid on the outside of the running rail. Continuous protective boarding is provided on the outside of the conductor rail, spaced sufficiently to allow passage of the shoe, while the rail itself has wood protection on its rear face, adjacent to the running rail, and on the top.

The power bus line running through each unit supplies the traction motor and h.t. auxiliary circuits. The whole of the h.t. system is insulated for 1500V, consisting of standard 1500V equipment modified where necessary for 1200V operation.

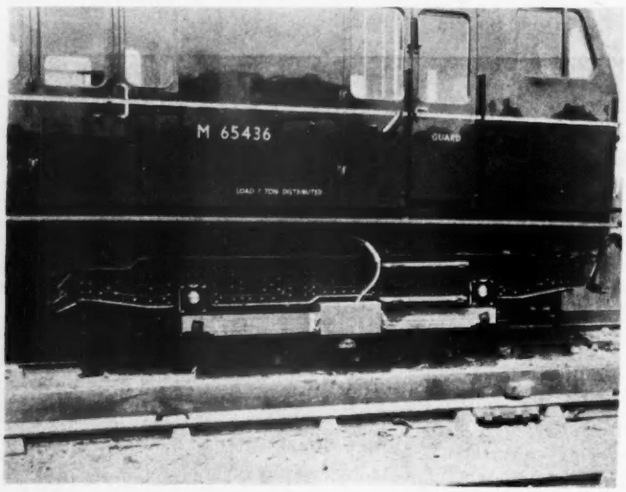


Section through shoegear and conductor rail

The electrical equipments have been supplied by The English Electric Company, Ltd. There are four traction motors to a unit, each having a continuous weak-field rating of 119 h.p. at 550V, 180A and 1168 r.p.m., with a gear ratio of 63/17 and 40in diameter road wheels. The motors are axle-hung, with sleeve suspension bearings and are self-ventilated.

The two motors of each bogie are permanently connected in series and are controlled by series and parallel connections of the two pairs. Two rates of automatic acceleration are available, and the electro-pneumatic contactor control scheme provides inching, series, parallel and weak-field notches on the driver's controller.

Heating supplies in each coach are taken from the 1200V bus line through h.t. contactors feeding 750V, 750W tubular heaters connected in series pairs. A 4·5kW totally-enclosed motor-generator and 80A-hour N.I.F.E. emergency battery furnish l.t. supplies at 110V. Passenger lighting in each unit is arranged in two 110V circuits, one of 1600W supplied from the motor-generator side of a reverse current contactor and the other, of 480W, from the battery side.



(Left) Train of new rolling stock on the Manchester–Bury line, London Midland Region, showing protected side-contact live rails. (Right) Shoe beam and side-contact collector shoe

SHORTER REPORTS

Competitive Design and the New Staines Bridge

IN the past two issues of THE ENGINEER, we have published without comment of our own, statements made in criticism and in defence of the design and cost of the Chiswick flyover. The main contractor for this scheme, the Alderton Construction Company, has now also criticised the design of another road bridge scheme, the Bell Weir Bridge at Staines. Apart from submitting the lowest tender for this bridge, the Alderton Construction Company also submitted, on its own initiative, a tender based on an alternative design by Ingerslev and Partners, its own associate company. Briefly, the company's second tender would have reduced the cost from £485,856 (the contract sum as accepted by the Ministry) to £285,000, and the construction time from twenty-one to fifteen months. A further £40,000 could be saved by further architectural simplification, it is claimed. The company's appraisal of the technical side of the problem is as follows :

" For the design of this bridge our hands were in many ways tied. An official scheme had been prepared which had been accepted by the many authorities involved, and we felt obliged—to avoid administrative delay—to retain the external appearance complete with brick facing and masonry balustrading, although to our mind a light open structure, which would not obstruct the scenery, would have been more appropriate to this beauty spot at Runnymede.

" The site is characterised by heavily waterlogged ground, usually flooded each winter, overlying plastic clay at a depth of about 25ft. Our aim was, therefore, to produce foundations which avoided having to open up the waterlogged ground which would have meant very large and very heavy and, therefore, costly, cofferdamming subject to flooding and consequent softening of exposed plastic clay.

" Secondly, we wanted to put as light a load as possible on the clay to avoid long-term settlements, and to select a superstructure that was least sensitive to settlements should such take place after all. These considerations led to a scheme which fitted well and naturally into the same shape as that of the official scheme, but now formed of a series of simple ' I ' beams in prefabricated prestressed concrete placed side by side, and cantilevered out from the piled foundations supporting a small suspended span in the centre, all made up in this fashion.

" Because economy in time of construction was a factor and also to enable as much work as possible to be carried out away from the possible flooding on the site, it was decided to divide the superstructure into precast sections which could be assembled by a large crane, the joints grouted, and the whole stressed together, thus making it a monolithic structure. The precasting also avoided having to cast the fairly tall and narrow walls vertically, as by casting them on the flat, and by manufacturing them in a factory, their high quality—assuring longevity—could be guaranteed.

" The construction of the actual bridge on site now became a very simple and fast operation, as the piled foundations and pile caps at approximately ground level could be constructed in a very short time and with no permanent effect from possible flooding. Simultaneously the precasting could proceed and the erection would then proceed as follows, without at any time obstructing river traffic.

" The soffit of the bridge is made up of inverted prestressed ' T '-beams, each 60ft long and making up one-third of the span. The sections reaching the abutments are put up first, supported at one end on the piled foundation, and two-thirds of the way to the other end on temporary supports (timber piles) erected in the river, leaving more than the centre half of the river free for river traffic.

" Vertical panels are then erected on the piled foundations and on the centre rib of the inverted ' T '-beams, the junctions grouted, prestressing cables threaded through, gradually tying the structure together and anchoring it back to the *in situ* concrete anchor block over the piled foundation furthest away from the river ; horizontal panels then placed between the flanges of the inverted ' T '-beams and the whole stressed together across the width of the bridge to form one continuous curved soffit. The cross cables are placed for convenience on top of the precast horizontal slabs and concreted in with *in situ* concrete on top of the slabs.

" Similarly, precast prestressed deck slabs are placed spanning from rib to rib, prestressing cables placed on top and *in situ* topping added before the whole is stressed or tied together, thus acting as one continuous prestressed slab spanning crossways from rib to rib.

" For lightness and economy, it was essential to have as few ribs as possible. On the other hand, the distance between them was governed by the deck having to carry not only the Ministry of Transport loading, but also the abnormal loading, and thus limiting the economical span of the deck. Cross panels were provided at regular intervals to ensure stability of the ribs and to ensure the working together of the several ribs. The central third of the bridge is designed in a very similar manner. They are to be supported on bearings on the cantilever portions already constructed and could easily be erected by the crane standing on this already constructed part.

" It will be seen that horizontal forces have everywhere been avoided on the foundations and this principle also applies to the approach embankments. The embankments instead of ending against a retaining abutment are merely carried under the cantilever at this natural angle of repose."

In justification of its rejection of this scheme and also of the lowest tender, the Ministry of Transport and Civil Aviation has issued the following statement :

" The first design of the Staines Bridge was prepared in 1939 by the consulting engineer, Mr. H. W. Fitzsimmons, in collaboration with Sir Edwin Lutyens as consulting architect. The design, which was for a reinforced concrete arch with brick and masonry facework, was approved by the Royal Fine Art Commission. When the project was brought forward again in 1957 the Commission was again consulted and advised that the original architectural features should be retained. As Mr. Fitzsimmons and Sir Edwin Lutyens had both died, the Ministry appointed Messrs. C. W. Glover and Partners as consulting engineers with Mr. George Stewart as consulting architect.

" The consulting engineers were of course free to recommend the most suitable structural design for the new bridge and, after reviewing the original scheme, they proposed that an alternative design be adopted for a steel and concrete framed arch construction supported on cellular concrete abutments. This revised design was accepted by the Ministry.

" The main features of the design are as follows : (*a*) The arch has been designed specifically for speedy and simple erection and without any temporary construction in the river. The welded steel ribs will be prefabricated and placed across the river to form a temporary construction bridge on which the rest of the superstructure will be built. (*b*) The steel ribs will later be encased in concrete to form a composite reinforced concrete structure. (*c*) The abutments supporting the arch will be of cellular concrete construction taken down below the poor overlying strata to the stiff London blue clay. The cellular construction of the abutments will minimise the load on the clay and ensure a uniform distribution of the load.

" Tenders were invited in 1959 for the construction of the bridge on this design and the Alderton Construction Company submitted a tender which was the lowest by a small amount. The Ministry decided, however, to accept the next lowest tender from W. and C. French, Ltd., because the firm undertook to complete the bridge in twenty-one months compared with the period of twenty-four months submitted by the Alderton Construction Company. This saving in time is significant as there are advantages in completing the bridge in advance of the scheduled time for completion of the roadworks on either side.

" The Alderton Construction Company also submitted a tender based on an alternative scheme prepared by Messrs. Ingerslev and Partners. This design consists of precast prestressed construction with extended cantilevers from each bank and a suspended centre span. In the view of the Ministry and the consulting engineers, this design was unsatisfactory because it contained serious defects which made it unsuitable for a bridge of this importance. For example, from the sketch plan submitted, the footings appeared to be founded at too high a level ; the piling was not properly supported through the poor strata overlying the blue clay ; the steel sheet piling was not an adequate protection of the foundations against scour from the river ; and the uneven loading on the foundations was likely to lead to differential settlement over a long term. Further, as regards the superstructure, it is considered that the light nature of the design would be likely to result in flexure of the deck which would cause cracking in the facework.

" If the Ministry had found it possible to entertain the alternative design it would in fairness have felt obliged to invite the other eleven firms who submitted tenders also to submit alternative designs if they so wished. It would also have been necessary to proceed to open tender if an alternative design had been chosen. This process would have greatly delayed the construction of the bridge.

" Separate from the question of the merits of the design of Messrs. Ingerslev and Partners, the Ministry points out that it is its well-proven practice to appoint leading consulting engineers to prepare designs for bridges and to appoint the same consulting engineers to supervise on its behalf the work of construction when the contract for the bridge is let. Furthermore, it is important that the consulting engineer should be completely independent of the contractor. The Ministry understands that the members of the firm of Ingerslev and Partners, consulting engineers, are the same persons as the directors of the Alderton Construction Company."

Instrument Research Laboratories

A NEW laboratory block at the premises of the Cambridge Instrument Company, Ltd., Chesterton Road, Cambridge, was opened by Lord Adrian on October 14. The buildings comprise a three-storey entrance block and the main laboratory block, consisting of four floors, each approximately 100ft long and 40ft wide. Each floor has a separate function, namely, mechanical engineering at ground level, physics and electronics on the first floor, physical chemistry on the second, and the design and drawing-office on the top floor. In the adjacent entrance block a spacious hall provides a reception area for visitors and contains in one wall a large showcase used for the display of different aspects of the company's activities. A corridor and staircase give access to the various laboratory floors, on each of which the experimental or working area is laid out on an " open vista " plan.

The clean, functional lines of the main building are accentuated by large windows running the length of the first three floors, underlined with panels of Westmorland green slate contrasting

Electron-scanning microanalyser for metallurgical analysis

with light buff brick facing on the side walls. The top floor has a long covered balcony overlooking the River Cam and Jesus Green. The building contractor was J. Jarvis and Co., Ltd., who worked to the design of the architects, Messrs. Edward D. Mills and Partners.

In visiting the laboratories and adjoining works departments after the opening ceremony, we had the opportunity to inspect various projects in course of development as well as the assembly and testing of apparatus already in large-scale production. Attention was drawn to moving coil galvanometer movements under test in which short metal bands under tension replace normal jewelled pivots. Not only is a very long life claimed under severe vibration, but it is expected that the majority of faults encountered in moving coil instruments in industrial use will be eliminated by the strip suspension, which serves also as a control force and electrical connection to the moving coil. Elsewhere in this section a small experimental moulding plant for certain nylon components was seen, and it was also stated that the company produces its own special-purpose glasses.

In the medical laboratory an exhibit illustrated the development of cardiographs, leading to the company's fully-transistorised "Transrite" instrument, now being introduced. This incorporates a heated-stylus recorder in overall dimensions of 12½in by 7in by 11in and may be operated from five standard dry batteries. Also shown was the company's "Ultramicrotome," with a feed mechanism operating through a micrometer and lever system designed to give sections of known thickness in steps of 50 Angstroms from 100 to 1500 Angstroms.

Several exhibits related to the company's work in the analysis of gas in liquids, particularly the measurement of oxygen and hydrogen content in water. This is becoming of growing importance now that increasing temperatures and pressures in boilers are limiting the permissible quantities of oxygen. The company has developed an electro-chemical dissolved oxygen recorder in which hydrogen transfers the dissolved oxygen physically from the feed water to an electro-chemical measuring cell which produces a current proportional to the concentration of oxygen in the hydrogen. This current is measured by a self-balancing potentiometric recorder calibrated normally in parts per million dissolved oxygen in water. Flue gas analysis is another subject of study, and an apparatus was shown for measuring oxygen and CO_2 content after magnetic deflection of the oxygen, using its paramagnetic properties. Work is also in progress on an improved method of determining carbon monoxide concentrations which will permit the development of small, semi-portable equipment for use in road tunnels, underground workings, underground car parks and similar sites where conditions may preclude the use of more bulky apparatus. Lines of study include reduction in size of the air drier and of the volume of the air sample necessary for measurement.

Electrical and electronic exhibits included the second production model of a precision voltage measuring console developed in conjunction with the Sperry Gyroscope Company, Ltd., incorporating a standard cell block, temperature control arrangements, and mirror galvanometer for voltage indication, with provision for attachment to air-conditioning plant when required for service in conditions of extreme heat and humidity. An accuracy of one part in 100,000 is obtained in measuring d.c. voltages up to about 48V.

Of the many types of apparatus on view, we illustrate a microanalyser for non-destructive metallurgical analysis in which an area up to ½mm square at 20kV of the surface of a metallic sample is scanned by a fine-focus beam of electrons, resulting in the emission of X-rays which are passed to an X-ray spectrometer. In the illustration the electron gun is seen on the control desk on the left, while the two display tubes in the centre cabinet show simultaneously an electron image and an X-ray image of the sample, so that a direct visual comparison between the surface topography of the specimen and the distribution of a selected element can be made.

[Reply Card No. E4832]

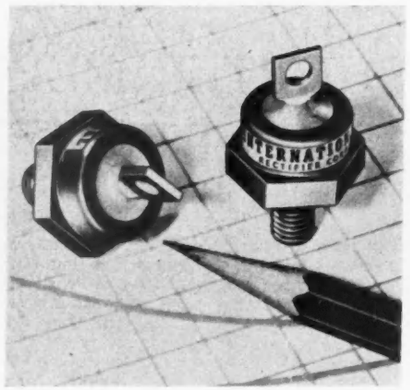
Aerial Photographic Exhibition of Quarries and Mines

A SPECIAL exhibition of aerial photographs of quarries and mines opened at the Geological Museum, Exhibition Road, South Kensington, London, S.W.7, on Thursday, October 15. Admission is free. The exhibition will remain open for several months. The photographs show past and present surface aspects and effects of quarrying and mining in the United Kingdom including views of famous mining areas in Cornwall and the Mendips, first exploited in Roman times or earlier; and of the great modern open excavations and quarries for iron-ore, limestone, coal, brick-clay, china-clay, sand and gravel, building stone, road stone and other raw materials which are an essential part of modern economy. The exhibition illustrates the great variety of useful rocks and minerals found in this country; and the special view of the aerial camera, which picks out mines and quarries in sharp contrast to their surroundings, emphasises the need for careful planning of their extraction—so that disturbance to the land surface may be kept at a minimum and rehabilitation provided whenever possible. All the photographs exhibited are from the Cambridge University Collection. They have been taken during recent years by Dr. J. K. St. Joseph, Curator in Aerial Photography at Cambridge, from aircraft of the Royal Air Force on training flights.

Silicon Junction Power Diodes

A SERIES of silicon diodes now being marketed in this country by the International Rectifier Company (Great Britain), Ltd., Hurst Green, Oxted, Surrey, embodies a four-layer process of sealing the silicon junction for maximum resistance to humidity, shock, vibration and temperature extremes. These layers consist of a Class H insulating varnish, an acid-resistant varnish, a resilient sealant allowing expansion and contraction of the assembly under temperature loads, and a high-temperature sealant. The last-named forms the outer seal with a hard layer dimensionally and physically stable over an operating temperature range from −20 deg. to +130 deg. Cent. Rectifiers with this sealing system are described as "Quad-sealed."

The rectifier ratings are 25A to 35A, 50 to 500 peak inverse voltage. Maximum reverse leakage current is 10mA, full-cycle average, at



Miniature silicon diode rectifiers with ratings up to 35A, 500 P.I.V.

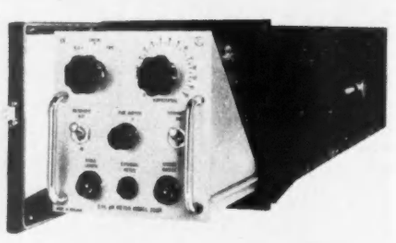
130 deg. Cent. base temperature. The large anode lug, seen in the illustration, assists in dissipating heat from the rectifier junction and enables high peak current surges to be withstood. A curve published by the manufacturer shows that a diode at ambient temperature, before any continuous load is applied, will sustain 300A peak for one second on a 60 c/s supply, when mounted on a 3in by 3in by $\frac{1}{16}$in aluminium cooling fin and forced-ventilated. The rectifiers are thus able to withstand starting surges involved in d.c. motor operation. A typical forward voltage drop at 50A average d.c. output in half-wave rectification is approximately 1·25V. Overall height of a rectifier is 1·219in, maximum diameter 0·688in, and approximate weight 1 oz.

[Reply Card No. E4842]

Panel-Mounting pH Meter

IN order to provide a pH meter suitable for mounting in panels with other miniature process control instruments, Electronic Instruments, Ltd., Lower Mortlake Road, Richmond, Surrey, has introduced an industrial instrument, model "28AM," for operating an external recorder, controller or moving coil meter. This has resulted in a device of much reduced frontal area, the panel size being 6in square. Overall length of the unit as illustrated is 22⅝in. The electrical output is suitable for most potentiometer or current-operated devices, or the meter may be used with an electro-pneumatic converter.

Power supplies may be 100–125V or 195–250V, 50 c/s or 60 c/s, and the power consumption is



Panel-mounting pH meter for operating remote indicator or controller

40W. Dip and continuous flow electrode systems are available. The circuit consists of two balanced d.c. amplifiers each with two stages in cascade and coupled back to back so that each acts as a cathode follower connected across part of the output load of the other. A temperature-compensating system corrects both for variations in the pH/mV relationship and for e.m.f. zero shift of the electrodes due to temperature. The instrument may be set up in a known buffer solution at one temperature and will then operate at any other temperature without adjustment or correction. Output is 100 microamp per pH into a load of 1500 ohms, and the ranges are 0–7pH, 0–10pH and 0–14pH.

[Reply Card No. E4843]

Mass Spectrometer for Respiratory Studies

A PROTOTYPE mass spectrometer for respiratory studies has been in use at the medical school of Hammersmith Hospital since 1956. This instrument was developed as a result of close collaboration between Dr. K. T. Fowler, then of the Post Graduate Medical School of London, and the mass spectrometry team of Metropolitan-Vickers Electrical Company, Ltd., Trafford Park, Manchester, 17. Experience with the equipment has now led to the production by the company of the first commercial mass spectrometer made solely for respiratory work.

The " Metrovick " mass spectrometer, "MS4," provides a simple method for the continuous analysis of expired gases at the lips, and results are presented as a printed record, on meters, and on a monitor cathode ray tube. A probe may also be used. The apparatus will measure simultaneously the concentration of any four selected gases in the mass range 17 to 50, covering the full respiratory range from water vapour to carbon dioxide. Previous mass spectrometers made by Metropolitan-Vickers Electrical Company, Ltd., have not provided this simultaneous four-channel facility, and while the present equipment, which we saw demonstrated in London last week, is specifically medical in application, similar apparatus could perform a useful function in industrial process control.

Control, recorder and tube units (left to right) of mass spectrometer for continuous analysis of expired gases

Analysis in a mass spectrometer is performed by the separation of the molecules in the gas sample according to their molecular weights. This separation is achieved by bombarding the molecules with electrons to produce ions, which are accelerated (in a high vacuum) into a magnetic field which deflects them through angles up to 180 deg. Since the deflection is greater for light than for heavy ions, the ion stream separates into separate beams of different molecular weight. As the accelerating voltage on the ion source is gradually reduced by the discharge of a capacitor, beams of ions of successively greater mass pass through a single slit giving access to a collector plate. The plate is scanned continuously by an electron beam and the minute currents to which the presence of the ions gives rise develop voltages suitable for amplification across a high-value resistor. The capacitor which controls the passage of the ion beams past the " gate " leading to the collector plate is charged and discharged twenty-five times a second. An indication of the number of ions in each beam is given by the amplitude of the collector plate currents, and so the proportion of molecules of different weight which are present in the beam may be found.

The apparatus is housed in three mobile cubicles as illustrated. From left to right these are the control unit, recorder unit, and tube unit. Only electrical connections are required between these units. The tube unit contains the analyser tube and associated pumping equipment, and the electron beam supplies. The vacuum pumps used for evacuation of the tube are a " Metrovac AO22 " air-cooled oil diffusion pump and a " Metrovac DR1 " rotary vacuum pump. The pump used on the sampling system is also a " DR1."

In the control unit are incorporated all the controls for operating the mass spectrometer direct from the mains supply. The main amplifier is coupled to the following circuits in such a way that although the individual stages are d.c. amplifiers, the overall effect is that of an a.c. amplifier. This removes the necessity for the highly stable power supplies essential with d.c. amplifiers. The equipment is supplied normally for 230V, 50 c/s, mains and consumes 3·5kW. A 60 c/s model can be supplied as an alternative.

At the top left of the control unit can be seen the cathode ray tube showing the full mass range being scanned. Below it are the meters for reading selected peaks in the range, which are picked out by operating controls on sub-chassis below each meter. Peaks selected are indicated by a brightening of the cathode ray tube trace. The tube may be connected into a number of points in the circuit for monitoring waveforms by means of a wander plug and jacks.

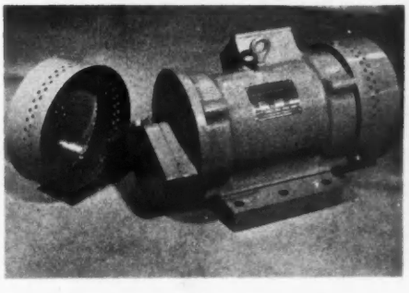
The recorder used is a " Sanborn " heated stylus recorder with four channels. The four recorder amplifiers are mounted below it. Nine paper speeds between the limits of 0·25mm per second and 100mm per second are provided and the 200ft roll of waxed recording paper allows approximately three hours of recording at the usual paper speed of 5mm per second.

An equipment of the type described is being shipped to the Department of Medicine of the University of Sydney, and another is on order for the Royal Air Force School of Aviation Medicine in connection with the high altitude chamber, where it will be used for investigating the effects of explosive decompression.

[Reply Card No. E4851]

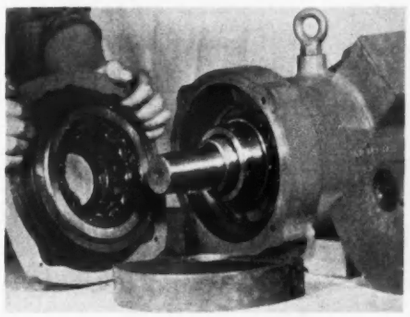
Electric Motor for Vibrating Drives

WE illustrate a new electric motor which is specially designed for vibrating drives and is being produced jointly by The English Electric Company, Ltd., Bradford, and the Grantham Electrical Engineering Company, Ltd., Grantham, Lincs. It can be used wherever vibrating motion is needed, as in drives for conveyor, screening, hopper and continuous drying systems and in machines for tamping, crushing and grinding.



In this motor for vibrating drives the vibration is produced simply by adjustable out-of-balance weights mounted on each shaft extension

In these motors, vibration is generated by out-of-balance weights fitted at either end of the motor. The weights are secured by single bolts and can easily be adjusted to give the required output. The motor is of robust construction with heavy-duty permanently-lubricated bearings to carry the out-of-balance loading inherent in this kind of duty. The makers report that tests have indicated a life expectancy of several thousand hours. High tensile steel is used for the shaft, the motor is totally enclosed, dust-proof and weatherproof and the frame is of nodular cast iron with integral feet. The motor is built to B.S.2613, with class-E insulation on the windings, allowing a temperature rise of 65 deg. Cent. above an ambient temperature of 40 deg. Cent. Normally it is available for operation on three-phase 50 c/s supplies at 110V to 650V.



Permanently-lubricated heavy-duty bearings of vibrating-drive motor

Because of its vibratory motion the motor must be mounted on a resilient base.

The main particulars of the range are tabulated here :

Vibrating Drive Units in Current Range

Type	Horsepower	Synchronous speed, r.p.m.	Centrifugal force, lb
V150/2	½	3,000	2,000
V150/4	½	1,500	1,120
V1100/2... ...	1	3,000	3,400
V1100/4... ...	2	1,500	2,463
V1200/2... ...	1½	3,000	5,500
V1200/4... ...	1½	1,500	4,938
V1300/2... ...	1½	3,000	10,000
V1300/4... ...	1½	1,500	7,408

[Reply Card No. E4852]

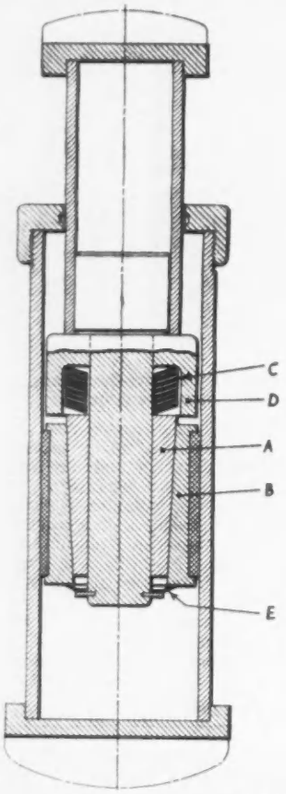
Planté Cells for Standby Power

INTRODUCTION of a new range of Planté batteries is announced by Chloride Batteries, Ltd., Clifton Junction, Manchester. They are stated to effect a saving in space of up to 50 per cent compared with cells made to B.S.S.440, with a reduction in weight. Improved performances at high rates of discharge are quoted, ranging from an increase of approximately 14 per cent at the one-hour rate to an increase of 100 per cent at the three-second rate of discharge. The cells have been specially designed for standby duties entailing discharge rates between the three-hour rate and the very high rates demanded for switch-closing purposes. They are well suited to trickle-charge operation and are now being fitted in all " Keepalite " emergency lighting units. Other applications are switch-tripping, telephones, supervisory and signalling duties. The fourteen sizes of cells in the new range have capacities between 15Ah and 400Ah at the ten-hour rate of discharge. For duties requiring extra-high currents the cells can be supplied with copper inserts in the pillars to increase conductivity. These units of exceptionally low resistance widen the field of application to include stationary engine starting, " no-break " or continuity sets, standby diesel plants, circuit breaker closing solenoids and essential services for nuclear reactors.

[Reply Card No. E4853]

Yield Mechanism for Friction Props

A FORM of construction by which telescopic friction props are given yield characteristics closely approximating to those of hydraulic props has been devised at the National Coal Board's Central Engineering Establishment at Stanhope Bretby. It is claimed that the yield load of the prop is achieved with negligible initial convergence and then remains practically constant for the remainder of its travel. The yield load is governed by a very highly rated spring which is shown diagrammatically in our illustration.



Arrangement of yield mechanism in a friction prop

The mechanism consists essentially of inner *A* and outer *B* annular wedges. When the prop is subjected to a collapsing axial load, radial pressure is created between the outer wedge and the inside surface of the prop's lower tubular member and the frictional force so developed creates the necessary yield load of the prop.

The roof load imparted on the upper telescopic member is transmitted to the inner wedge through the very highly rated spring *C*, which can be provided by a bank of Belville washers or stiff rubber rings. At the required yield load the deflection of this spring assembly allows an abutment, *D*, at the base of the upper member, to contact the top edge of the outer wedge, *B*, and thus prevent any further tightening action between the wedges. The outer wedge is of segmented construction so that it can expand radially as the inner wedge is pushed into it. Keys provided between the segments prevent any relative movement other than the radial expansion. The surfaces of the outer wedge segments have friction pads bonded to them to grip the inner surface of the lower member.

Since the wedges are self-tightening, it is only necessary to provide a small initial grip between them as a basis for the increase of resistance. This initial grip is provided by a retaining spring, *E*, inserted between an extension of the inner wedge and the bottom of the outer wedge.

The prop is set by driving in a setting wedge which raises the cap up into contact with the roof or roof bar. To release the prop the setting wedge is first driven out to lower the prop cap and a release wedge is then used to break the grip between the yield mechanism wedges. The main advantage of this mechanism is that the yield load of a prop is controlled automatically.

Amplifiers for Servo Systems

WE have received particulars of new transistor and magnetic amplifiers for use with Pullin Size 10 and Size 15 servo-motors from R. B. Pullin and Co., Ltd., Phoenix Works, Great West Road, Brentford, Middlesex. The transistor amplifier "TA.1.G," is designed to provide the control phase power for a Pullin Size 10 servo-motor or Size 10 motor-generator, but will also drive any suitably-wound Size 15 servo-motor or, through a centre-tapped transformer, other forms of load. The amplifier circuit consists of two stages of pre-amplification directly coupled to a driver stage, followed by transformer coupling to a pair of output transistors. A balanced 400 c/s supply of 26V is used normally, and undergoes full-wave rectification by a pair of silicon diodes, but the amplifier may also be powered with 18V d.c. Nominal output power is 4W at an ambient temperature of 55 deg. Cent. but up to 6W can be obtained below 50 deg. Cent. Two terminals and a built-in resistor of 22kΩ are provided as a summing point for several signals in feedback systems, and other summing resistors may be added externally.

Most of the amplifier components are mounted on a printed card, and the whole assembly is moulded into a block of silica-loaded resin measuring 2¾in by 2¼in by 1½in (including connector spills), and weighing 12 oz.

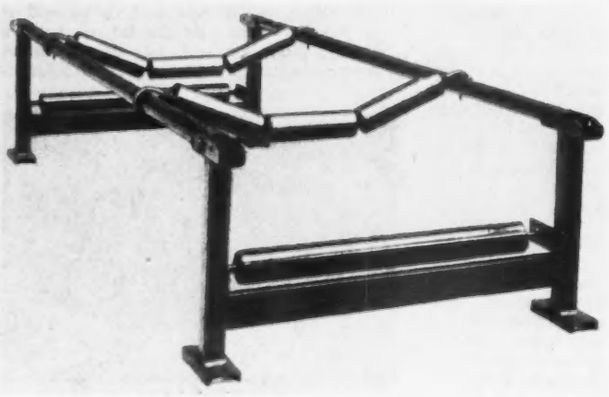
The Pullin-Kearfoot magnetic amplifier is made in two versions, "R601-1" for ambient temperatures at −55 deg. Cent. to +71 deg. Cent., and "RH601-1" to special order for ambient temperatures from −55 deg. to +125 deg. Cent. It is for use with Size 15 servo-motors and gives a power output of 5W maximum in the form of a phase-reversible a.c. signal to the servo-motor control phase. Input to the control winding may be a directly-applied d.c. signal of reversible polarity or alternately-switched positive and negative signals from an external double-triode operating on 220V, 400 c/s. The amplifier primary is for connection to a 115V, 400 c/s supply. The amplifier measures 3½in high overall by 1½in by 2¼in and weighs 18 oz.

[Reply Card No. E4862]

Troughing Idler Belt Conveyor Structure

AN idler belt conveyor structure developed by the Mining Engineering Company, Ltd., Worcester, has idler assemblies in which the troughing angle increases under loaded belt conditions to enable the maximum carrying capacity of the belt to be used without spillage. When the belt is unloaded it is only shallowly troughed into contact with a centre idler so that it is effectively trained.

As shown in the illustration the main conveyor structure is of light, simple construction with stools made from rectangular tubes connected by a welded cross member. A 4in diameter return roller above the cross member positions the belt 1ft above floor level. These rollers are adjustable for belt training purposes. Tubular stringers are secured in the cradle tops of the stool legs by simple knock-out pins, and the form of connection, whilst imparting lateral rigidity, gives a degree of vertical flexibility to enable the structure to follow undulations in the floor.



Idler belt conveyor structure in which the troughing angle increases in proportion to belt loading conditions

Each idler assembly consists of three rolls rotating on sealed, grease packed ball bearings, the centre roll being coupled at each end by flat chain links to the inner ends of the side rolls. A heavy spring assembly enclosed within each side roll is coupled to hooked bars which are used to suspend the idler resiliently in the main structure. Steel clips located in spigots in holes in the stringers receive the hooks and position the idlers in the structure.

It will be appreciated that with this form of idler construction the idlers trough against the spring loading in relation to the weight of material on the belt up to the limit imposed by the restriction of spring yield. When a belt is unloaded the idler troughing angle is about 20 deg. and this angle increases progressively with belt loading up to a limit of about 35 deg. with a fully loaded belt. In a typical structure of this design such as that illustrated the stools are set at 9ft centres with the idlers at 4ft 6in centres.

[Reply Card No. E4863]

Welding Equipment for Thin Materials

WE are informed by Quasi-Arc, Ltd., Bilston, Staffs, that a new equipment known as the "Sigmette" has been introduced for the rapid semi-automatic welding of light gauge ferrous and non-ferrous metals. The equipment is based on the established "Sigma" process, using a continuous coil of bare wire electrode and shielding by argon gas or by carbon dioxide. With the new equipment welding is carried out by what is known as the "short-arc" technique, whereby the metal transfer is in globular form, as distinct from the "spray" type of transfer normally associated with "Sigma" welding.

"Sigmette" welding gun for thin materials. This gun is continuously rated at 125A for 0·030in wire and 200A for $^{3}/_{64}$in and $\frac{1}{16}$in wires

A portable lightweight gun used with the equipment enables welding of all materials to be carried out in every position, including vertically and overhead, as only the gun needs to be carried to the work. The process has further advantages when welding relatively thick materials, as the operator can weld comfortably in confined spaces or in areas remote from power and gas supplies without having to move heavy equipment.

The welding gun, which is illustrated above weighs only 3 lb 1 oz, and is designed to carry a spool having either 1 lb of aluminium or 2½ lb of ferrous wire. This weight of wire is

sufficient to enable welding for periods of up to three-quarters of an hour on one spool. In the gun the wire is positioned initially by use of an inching button in the base of the handle. Subsequent pulling of the trigger starts the gas flow and initiates a slow wire feed, and as soon as the arc strikes the full wire feed speed comes into operation at a rate which is set by adjusting a knob on the voltage control unit.

The gun handles three sizes of wire, and it is continuously rated at 125A for 0·030in wire and at 200A for $^{3}/_{64}$in and $\frac{1}{16}$in wires. The standard medium-speed wire feed motor fitted gives a wide range of applications with all wire sizes. If required, high-speed or low-speed motors can be supplied for special work when using 0·030in or $\frac{1}{16}$in wires. The motors are interchangeable and the complete range of applications can be covered using only one gun.

A compact voltage control unit, weighing just over 19 lb, controls all the welding variables including wire feed speed and gas flow, and once they have been set they are automatically operated by the trigger control on the gun. Standard 30ft leads are fitted between the control and gun to permit a wide radius of operation without having to move the equipment. For the d.c. power supply it is recommended that the maker's "MFB 225" lightweight motor generator set is used. This machine has an output current range of 20A–225A at 45V–60V open circuit. When used with "Sigmette" equipment a contactor cubicle is supplied comprising a 200V/250V single-place 500VA transformer with a 115V secondary supplying operating current to the gun and control, and a contactor continuously rated at 200A.

[Reply Card No. E4864]

Versatile Analogue Computer

THE forthcoming introduction of a multi-purpose analogue computer embodying numerous developments of importance to the scientist and mathematician, is announced by Short Brothers and Harland, Ltd., Castlereagh, Belfast. Basically the instrument is a 112-amplifier linear computer and consists of seven standard racks fronted centrally by a double-pedestal desk. Variations to meet individual requirements can be obtained by plugging specified components into the standard racks. Up to nine special non-linear components can also be incorporated if desired.

A new amplifier unit has been designed for this computer, having a main amplifier gain greater than 10^5 and a short-term drift better than 10μV in order to maintain an accuracy of 0·01 per cent. The amplifiers are contained in one rack of each twin-rack unit beyond the ends of the control desk. The other rack of each unit is a double-walled, temperature-stabilised oven containing the passive elements. All units plug in from the front, the temperature-sensitive elements being at the rear of the sub-chassis. The rear of each sub-chassis enters an inner enclosure which is maintained at a constant temperature ±0·5 deg. Cent.

A highly flexible form of patch panel has been evolved with the object of relieving the operator of unnecessary work. Any passive element output may be connected to any active element input in one half of the panel, and any active element output to any passive element input in the other half. These connections are made by single-pin plugs and single patch cords, none of which needs cross, although up to 100 cords may be employed per panel.

Potentiometers are servo-set to an accuracy better than 0·01 per cent in an average of less than one second. In addition, fourteen manually-set potentiometers are provided for variations within a problem. Selector buttons are used to connect any amplifier output to any measurement channel or to set up any potentiometer.

Thirteen measurement channels are provided, consisting basically of a six-channel mirror galvanometer recorder with ultra-violet printing, a twin-beam oscilloscope, three separate voltmeters, and a digital voltmeter displaying a four-digit decimal fraction of 100V accurate to 0·01 per cent.

[Reply Card No. E4871]

Automatic Stokers

A NEW automatic coal stoker, known as the "Vekos," is being manufactured by G.W.B. Furnaces, Ltd., Dudley, Worcestershire. In this stoker the coal is burned in a water-cooled combustion chamber and the hot gases of combustion directed into the boiler.

As can be seen in the diagram, a screw conveyor, which has a specified hourly throughput, carries the coal to the top of the combustion assembly and drops it into the vortex chamber where it is spread evenly in a thin layer on the fire-bed. The combustion air is divided into three separate volumes and introduced to the furnace at three different points so as to assist in providing a high combustion efficiency. Primary air is directed underneath the grate, in which the passages provide high resistance to the air flow, maintaining an even air pattern through the fire. Secondary air is directed over the hearth through a duct set tangentially in the vortex chamber, whilst the tertiary air is supplied at the throat between the stoker and the boiler. Each amount of air is set for optimum conditions and is provided by a common fan. The three dampers governing the various air flows are adjusted and pre-set in relation to each other.

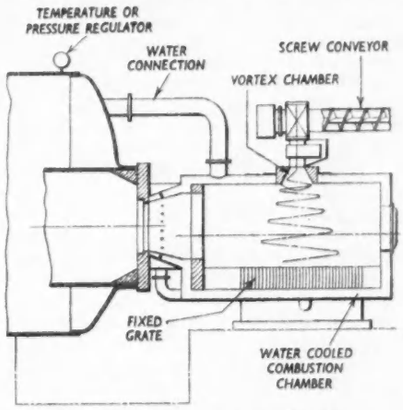
The fan and screw conveyor are controlled through either a temperature or a steam pressure regulator, depending upon whether the boiler is arranged for water heating or steam raising. When the required temperature or pressure is reached, the air and the fuel rates are automatically reduced to suit the load. When extra output is required, the air and fuel are again automatically adjusted to meet the increased requirements.

The stoker is designed to burn all types of bituminous fuels and even strongly caking coals. The makers state that these units have been successfully used in tropical countries for burning nut shells and husks left over after extraction of vegetable oils. Small coal may also be burnt, although it is advisable, in order to guarantee maximum efficiency, that the amount of fines below $\frac{1}{8}$in should not exceed 35 per cent and that the moisture content limits should be around 15 per cent. The upper fuel size would be of the order of 1in.

The special coal feed arrangement is designed to produce an even fire-bed, and it is claimed that a consistently high CO_2 value of 14/16 per cent is obtained under normal operation, without producing smoke. Infiltration of air into the side passes, as for example, with a brick-set boiler with induced draught, is considerably reduced, since the air supply to the "Vekos" stoker can be pressurised to offset the slight back pressure of economiser, superheater, and other resistances. In such cases it is normally necessary to break the natural chimney draught.

Maintenance of the stoker is said to be very simple, as raking of the fire-bed is not necessary, and the usual attendant problems associated with strongly caking fuels are eliminated. The furnace bed needs occasional cleaning, the frequency depending on the ash content of the fuel.

For these installations two methods of electric control are available, the first of which includes an on-off control, whereby at a predetermined boiler pressure or temperature, the unit is switched on or off. Should the periods when the stoker is switched off be excessive, the unit is simply adjusted to a lower level of working. The other method functions by means of "high/low" control, in which a screw conveyor motor having two speeds is employed. In this case,

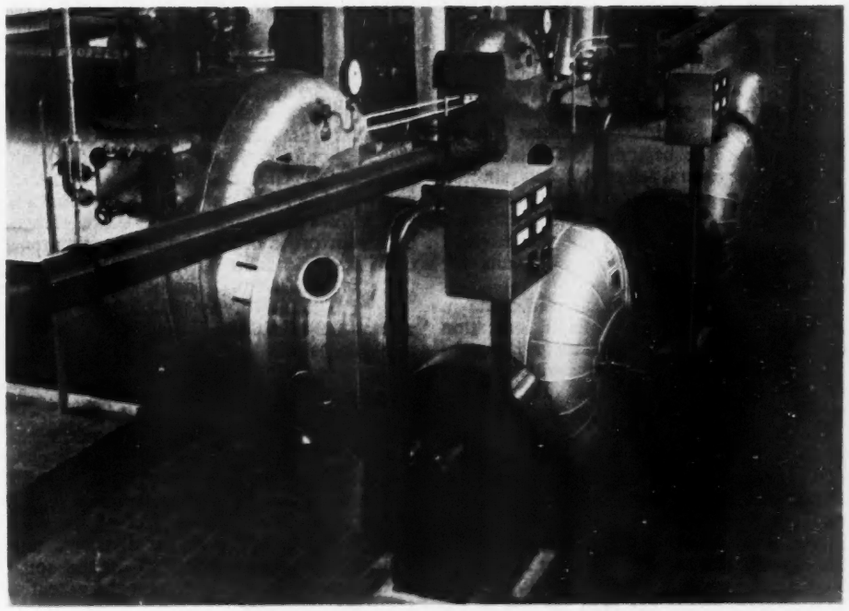


Diagrammatic cross section of stoker

instead of the stoker being switched off at a predetermined boiler pressure and temperature, the gearbox is changed to a lower speed and the air quantity is automatically controlled to give a constant fuel-to-air ratio. When the steam pressure or temperature drops, the unit is then switched back to normal maximum. This control is effective down to 50 per cent of the total capacity of the stoker.

The stokers can be used on most types of boilers and they are made in single units ranging from 165 lb to 770 lb coal per hour. Where required, twin stokers may be fitted, thus doubling the fuel-handling capacity up to a maximum of 1540 lb coal per hour.

[Reply Card No. E4872]



Boiler house with "Vekos," stokers, on two boilers with an output of 6000 lb steam per hour; and a third boiler with an output of 3600 lb per hour

Industrial and Labour Notes

Iron and Steel

The Iron and Steel Board's latest production statement shows that the improvement in the British steel industry, which has been steadily gaining strength throughout this year, continued during September. Pig iron production averaged 251,100 tons a week, which represents an annual rate of 13,057,000 tons, compared with a rate of 12,009,000 tons in September, 1958. Steel output in September averaged 426,400 tons a week and was thus at an annual rate of 22,171,000 tons, compared with 19,169,000 tons in September last year. In the third quarter of this year, steel production was 12 per cent higher than in the comparable quarter of last year, though it was still 6 per cent below the output achieved in the third quarter of 1957.

The Board says that steel production is likely to rise still further as additional capacity becomes available at the strip mills and as demand increases in other sectors of the industry. Cold reduced sheet production from the continuous mills in the first eight months of this year was 10 per cent up on the corresponding period of last year. It will be recalled that, in the Iron and Steel Board's last annual report, the hope was expressed that, as a result of new capacity coming into operation, home supplies of sheet would expand sufficiently to meet the rapidly growing demand and remove the need for imports by the end of this year. But the Board now says that teething troubles with new plant have slowed down this expansion a little. The most recent assessment indicates that supplies of cold reduced sheet from the continuous mills are expected to rise next year by about 25 per cent or by rather more than 400,000 tons over the present year's supplies.

Industrial Trends

The Federation of British Industries has recently completed another inquiry into industrial trends in the United Kingdom. It is the sixth examination of its kind made by the F.B.I. over the past two years, during which period, it is stated, "the industrial trends have changed from slightly downward to markedly upward." This latest inquiry was made at the beginning of this month (before the general election) and showed continuing expansion over a wide front. The improvement, the F.B.I. says, is expected to continue though it has not yet led to a corresponding expansion in the plans for capital investment.

In the fifth inquiry, which was made in June, an outstanding point was the indication of increased output. This trend has continued, 55 per cent of the firms which replied in October reporting output increases and only a scattered 8 per cent reporting decreases. The increases, the F.B.I. comments, are widespread but not universal. The number of operatives employed and the number of hours worked per man have increased more markedly than in June. That, it is stated, indicates a change of trend, more firms finding it harder to get the labour they need. This trend, however, is not strong. The cause of increased output has been the steady rise in orders received. Another reflection of the increased output is the fact that 50 per cent of the firms which replied to the F.B.I. inquiry are now working to capacity, compared with 20 per cent last February.

But, the F.B.I. adds, the point has not yet been reached at which there is widespread planning of new capacity. Here, the trends differ between buildings on the one hand and plant and machinery on the other. For the latter, the downward trend was checked in June. So far as new building is concerned, however, the downward trend, which was lessening in intensity up to June, shows no significant improvement in the October inquiry.

Export Prospects

The October issue of the *Export Guide*, which is prepared quarterly by The General Electric Company, Ltd., gives the prospects for thirty-six product groups of British exports to thirty-four major markets. It says that, for the remainder of this year, export prospects are "good" in seventeen countries, "improving" in thirteen countries, "deteriorating" in two countries and "bad" in two countries.

Commenting on the trade prospects in the "outer seven," the *Export Guide* says that the political will to agreement of the seven negotiating countries ensures that the European Free Trade Association will come into force by the middle of next year, when the first reduction in tariffs—20 per cent—on industrial trade between the member countries is due to take effect. There is no doubt that the considerations behind the European Free Trade Association of the "outer seven" are essentially political. But it is hoped to be a step towards a wider agreement on the lines of the original Free Trade Area proposals which came to grief at the end of last year. It is open to question, the *Guide* remarks, whether the new alignment will contribute to that object or whether it may not create further difficulties. If the two separate groupings continue their divergent ways for long, they will tend to loosen those very ties which at present encourage a wider grouping and the hoped for economic unity of Western Europe will be remote.

Last year, the "outer seven" countries, with a population of 37,000,000 people (excluding the United Kingdom) imported £2,954·7 million worth of goods from all sources. Of that total, £1324 million was imported from the Common Market countries and £372·8 million from the United Kingdom. In order of importance as importers of United Kingdom goods, Sweden comes first (£118,400,000), followed by Denmark (£109,100,000), Norway (£72,200,000), Switzerland (£34,400,000), Portugal (£21,900,000) and Austria (£16,700,000).

Trade Union Thinking

The David Brown Corporation has recently held a week-end management conference which was attended by thirty senior executives from its various factories in the United Kingdom. The object of the conference was to bring all the divisional and general managers together to discuss some of the broader aspects of current and potential industrial problems.

One of the papers presented for discussion was by Mr. Lewis Wright, chairman of the T.U.C. production committee. His paper was entitled "Trends in the Trade Union Movement." Mr. Wright prefaced it by saying that there were bound to be fundamental differences between the workers' approach and the employers' approach to various industrial problems. But, he added, in recent years especially, the trade union movement had realised that if workpeople were to improve their standard of living and if they were to get more of everything, then, first of all, there must be more of everything to get! That was why trade unions had interested themselves a great deal in productivity as well as in the need to produce more.

As to what could be expected of the trade union movement in these days, Mr. Wright said that a number of points must be kept in mind, points like the problem of co-operation, the attitude to productivity, problems of communication within firms and problems of redundancy because of technological change. When any undertaking was considering change, particularly the introduction of labour-saving machinery, it must consider the human problems involved from the very beginning of the exercise and not merely as something that must be looked at to avoid trouble. If employers ignored the "technical-human" equation, Mr. Wright commented, they were making a rod for their own backs. Technical efficiency could not be achieved at the expense of human dignity. One of the most restrictive bottlenecks to increased industrial productivity, Mr. Wright continued, was the problem of redundancy. Matters such as retraining and catering for changes through normal labour turnover should be considered in the initial stages of any development planning. If, when all was done, there were still some who could not be absorbed directly, then there should be something in the way of financial assistance until they could be rehabilitated within the firm itself or elsewhere. That, Mr. Wright claimed, was not just sheer generosity; it was essential to the achievement of increased productivity.

Electricity Council's Scholarships

The Electricity Council is sending to grammar and public schools throughout Great Britain details of sixty-one university scholarships which are being offered by the electricity supply industry. It is stated that the scholarships are worth £450 a year for three years at Oxford and Cambridge and £400 at other universities. Both boys and girls are eligible to apply. Scholars will be expected to read for degrees in science or engineering, to fulfil certain training requirements, and to return to the industry for two years after taking their degrees. There are no other "strings" attached to the offer.

The Council points out that the electricity supply industry is expanding rapidly and that modern technical advances, such as the development of nuclear power, make imperative the recruitment of highly-qualified technical staff. These scholarships are intended to help the industry to meet its future requirements for such staff. Last year, when the scholarship scheme was launched, forty-four awards were made, the holders of which are now beginning their university courses.

West German Synthetic Rubber Plant

THE Bunawerke Hüls, G.m.b.H., synthetic rubber plant at Marl, has an annual capacity of 45,000 metric tons. Its design was provided by its parent concerns, drawing on domestic and American experience in this field. The company had the technical assistance of the Houdry Process Corporation for butadiene production, and of Esso Research and Engineering Company for its concentration, as well as of the Firestone Tire and Rubber Company for the design of polymerisation and coagulation units. The design of the plant was carried out by the Engineering Department of Chemische Werke Hüls A.G.

To the sponsors of this undertaking it became obvious that for an all-round rubber to be used both in manufacturing tyres and other rubber goods and to be blended with natural rubber, only the butadiene-styrene co-polymer was suitable. At the end of the second world war German experience had established that butadiene was a good raw material for synthetic rubber and that emulsion polymerisation could be far better controlled in large-scale operation than the mass polymerisation process. The undesirable branching observed in emulsion polymerisation of butadiene alone could be reduced to a tolerable degree by the co-polymerisation of butadiene with mono-olefins.

The most suitable mono-olefin as a co-adduct to butadiene for an all-round rubber proved to be styrene. The free radicals required for carrying out the polymerisation process were supplied by peroxides. Modifiers were applied to reduce branching and the degree of polymerisation without reducing the rate of the latter. As a consequence processing of the product was rendered easier, but still entailed thermal degradation. Finally, it had become known that by the application of redox systems, at temperatures of around 41 deg. Fah. with good reaction rates, a rubber of good "processibility" could be obtained.

The corresponding formulations included, in addition to the peroxide catalysts, also reducing agents or in addition to oxidants and reductants also admixtures of ferro compounds. Other formulations contain complex iron and sequestering agents like ethylene diamine tetra-acetate ("Trilon B") to form heavy metal ion complexes. Aliphatic amines had, too, been applied as activators. Under war and post-war conditions these promising techniques could not be utilised in large-scale production in Germany. It was thus evident that the new German plant, aiming at the manufacture of a high-quality product would of necessity follow to a large extent the lines of development in the United States.

During preliminary planning of this German plant details of a poly-cis-1, 4-isoprene synthesis of a quality at least equivalent to natural rubber were published in the United States. In the meantime it also became known that 1, 4-cis-polybutadiene obtained by stereo-specific acting catalysts is a rubber.

The £15,000,000 Hüls plant is owned by Western Germany's four major chemical companies. Fifty per cent of the share capital of DM.42,000,000 is held by Chemische Werke Hüls, and 16⅔ per cent each by the Bayer, the Höchst and the Badische Aniline (BASF) groups. Designed for an initial production of 45,000 metric tons a year, this capacity is soon to be expanded to 70,000 tons, and eventually to 90,000 tons.

Of fundamental importance to the manufacture of synthetic rubber are the price and quality of the raw material, especially butadiene. Plans for producing butadiene via ethylene and ethyl alcohol were dropped because of the high investment costs involved. It was therefore decided that a petroleum basis for manufacturing butadiene would be expedient, the more so as the main consumer of rubber—the motor-car, in its capacity as major user of petrol—would safeguard the crude oil material basis. And since n-butylene was not available in sufficient quantity in the Federal Republic it was decided to employ n-butane as starting material for preparing butadiene.

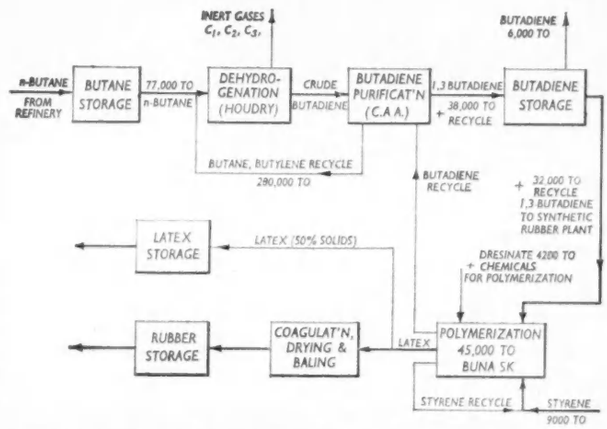


Fig. 1—Simplified flow diagram of Bunawerke Huls G.m.b.H. synthetic rubber plant. The figures represent throughput in tonnes per annum

The accompanying diagram, Fig. 1, gives a simplified outline of the process used in the German plant. The conversion of n-butane to butadiene is carried out according to the Houdry Process. In this catalytic dehydrogenation technique, operating at around 110 deg. Fah. and 2 lb per square inch absolute pressure, butylene and coke are formed in addition to butadiene, the coke being deposited on the catalyst. These reactions are highly endothermic. The heat is supplied by superheating the catalyst bed in an alternating cycle by hot air, followed by gas containing n-butane, when the excess heat is utilised for the dehydrogenation reaction. The fluctuation in temperature amounts to around 45 deg. Fah.

During the air heating periods the catalyst is regenerated by the combustion of the deposited coke. In theory, the heat of combustion of the coke will suffice to supply that needed for the process. In practice, however, a large supply of air is applied to heat the catalyst during the regeneration period as uniformly as possible. For superheating, approximately the heating value of the coke is required additionally as fuel gas. In this plant, the five minute dehydrogenation cycle is succeeded by a five minute regeneration cycle with air.

The switch-over which, for reasons of economy and safety, is accompanied by purging and evacuation, takes nearly two and a half minutes. The total cycle is resumed after fifteen minutes. Three reactors are successively operated in a continuous rotation. The control of switching-over from the dehydrogenation to the regeneration cycle necessitates a fully automatic mechanism, which is operated hydraulically and regulated by an electric cycle timer. During the dehydrogenation operation the catalyst loses in activity. For this reason the dehydrogenation unit was subdivided into two parallel systems of three reactors each, whereby each system could be shut down separately. Part of this section of the plant is shown in Fig. 2.

In West Germany the price of n-butane is far above that in the United States. In order partly to circumvent this handicap, efforts have been made to improve the yield and throughput of butadiene plants. The arrangement of reactors means a certain rise in capital costs, but it also confers certain operational advantages. Thus, it gives a continuous supply of butadiene whilst the catalyst is being replaced. Moreover, a better yield of the material is obtained since the individual periods are shortened and the overlapping time for purging between production and regeneration times is improved. The standard arrangement provides for two reactors each in production; two in regeneration and one in purging. In this plant the time for purging has been doubled. The high price of n-butane in Western Europe caused the German technicians to decide in favour of a process which would guarantee a safe and uninterrupted operation.

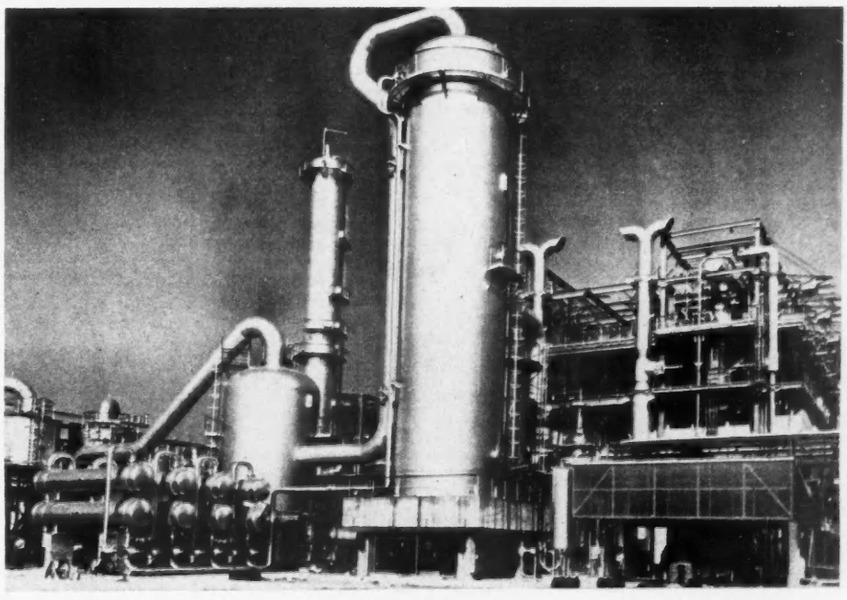


Fig. 2—Dehydrogenation plant for the production of butadiene from n-butane. In the foreground may be seen the cooling tower for the reaction gas. In the background are the separators for the preliminary purification of butadiene

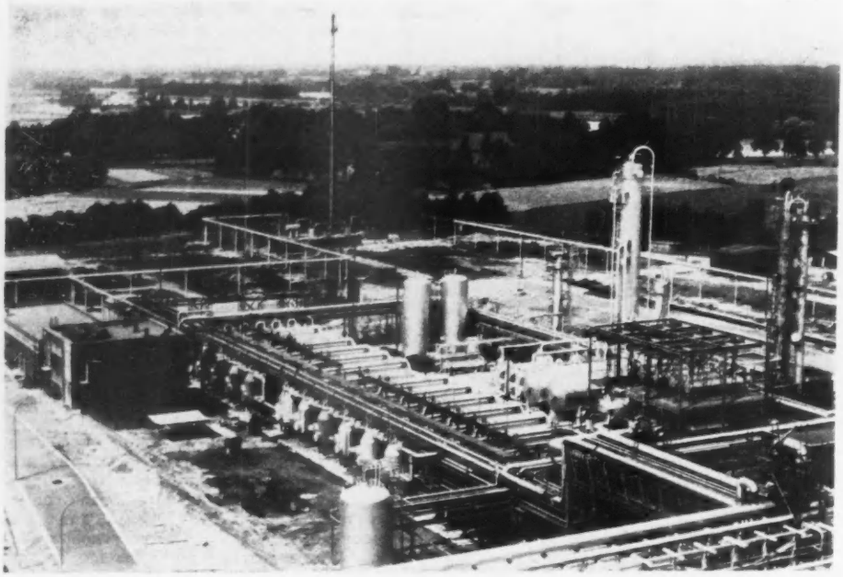


Fig. 3—Butadiene purification plant. Here the butadiene produced in the dehydrogenation plant is separated from all by-products and by distillation brought to the degree of purity required for polymerisation with styrene

The crude butadiene obtained by dehydrogenation has a concentration of approximately 12 per cent ; the balance is butylene, butane and a certain amount of iso-C_4-hydrocarbons. The recovery of butadiene from these hydrocarbons is carried out by the copper ammonium acetate extraction process, by which it is selectively removed at a low temperature. This technique was developed in the United States by Esso Research and Engineering Company and is operating satisfactorily. The butadiene obtained by this method and subsequent distillation has the purity required for the rubber synthesis. The butadiene concentration plant (Fig. 3) is additionally equipped for processing the butadiene not converted in polymerisation. It has, however, been found that this will accumulate by-products, which influence both yield in polymerisation and quality of the rubber produced. The styrene required for the rubber synthesis is made available by Chemische Werke Hüls adjoining the new Bunawerke Hüls plant.

The conversion of butadiene and styrene to butadiene-styrene co-polymer is operated continuously in two polymerisation batteries of ten agitators, each arranged in series. Each agitator has a capacity of 5300 U.S. gallons. Refrigeration of the contents is effected in a vertical tube system inside the agitator by means of evaporating ammonia. Special pumps feed the base materials for polymerisation, such as butadiene, styrene emulsifier, activator and modifier, jointly through a pre-cooler and into the first agitator. The oxidant is fed separately. The redox system employed is that of ferro-pyrophosphate, p-menthane hydroperoxide and "Trilon B" (U.S. trade name "Versene Fe-3"). Polymerisation is carried out at around 41 deg. Fah. about 50 lb per square inch gauge pressure.

As the quality of the polymer wanes with increasing conversion in the polymerisation due to branching, polymerisation is stopped at about 60 per cent conversion and at a fixed Mooney viscosity. To this end appropriate short stop chemicals are added to the latex in smaller agitators following the polymerisation battery. From this latex the unconverted monomer hydrocarbons—butadiene and styrene—are recovered by treatment with steam at reduced pressure in agitators and stripping towers. Subsequently, the latex containing approximately 25 per cent of solids is stabilised either by means of phenyl-β-naphthylamine or, for non-staining products, by such substances as distyrolised diphenylamine or phenol derivatives (2·2′-methylene-bis-(4-methyl-6-tert.) butylphenol).

The coagulation of the latex is brought about by means of sulphuric acid and rock salt solution. The action of H_2SO_4 is continued until the emulsifier is converted into the free rosin acid insoluble in water, which remains in the rubber. The rubber crumbs are washed with neutral acid and later, dehydrated mechanically by a squeezing action and finally dried in a channel drier. The dried product is baled in 55 lb blocks. The coagulation and drying for the entire plant is subdivided into three individual systems.

When the former I.G. Farbenindustrie A.G. planned the first large-scale continuous emulsion polymerisation plants for synthetic rubber, investigations were made as to whether it would be advantageous to carry out the process in a pipe system instead of by agitators, especially as in the pipe system removal of the heat of polymerisation could be controlled better than in the agitators. The 5300 gallon agitator is a unit which is easily controlled technically, and has so far yielded good results. Moreover, the polymerisation process is not merely a heat transfer problem ; it is also necessary to ensure a uniform average time of stay for the reacting components inside the system. For these reasons the company preferred to use agitators.

When the plant first came into operation last September, the world market price of synthetic rubber was DM.2·4 per kilogramme, compared with production costs in Western Germany of DM.2·65 per kilogramme. These, however, are expected to go down as output rises and efficiency improves. As a temporary measure, local tyre manufacturers have underwritten initial annual losses of DM.10,000,000 a year for five years.

The Hüls plant produces 45,000 metric tons per year of synthetic rubber. The range of production comprises : one quality of cold rubber stabilised with phenyl-β-naphthylamine one quality of cold rubber, non-staining, stabilised ; in addition, three different kinds of oil-plasticised rubber containing fifty, thirty-seven and twenty-five parts of oil per 100 parts of rubber ; and latices for various applications.

This plant is very fully "automated." Labour costs are less than 3·5 per cent of the total cost of production, probably the lowest ratio in any installation on the Continent. Capital outlay per worker is of the order of £35,000, and there are less than 400 employees. The value of a year's production amounts to £8,000,000.

The cold rubber tyres now marketed are generally processed in blends with natural rubber. They are better in quality than natural rubber, especially with regard to abrasion, and they possess good ageing and weathering properties. For processing without admixture of natural rubber further developments of the qualities of the synthetic product will be necessary.

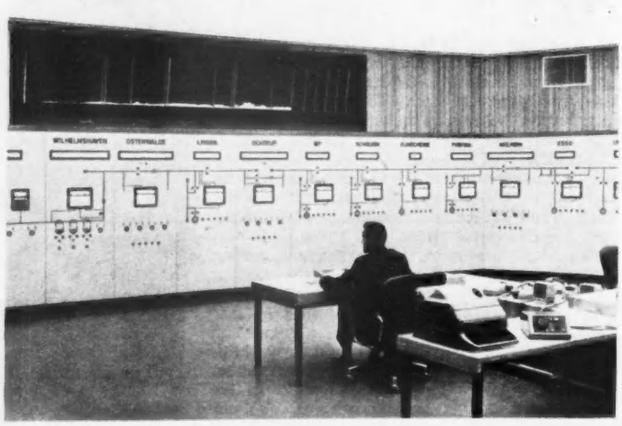
Compared to natural rubber, cold rubber is not quite satisfactory concerning tack in crude rubber and tear resistance. Past developments starting with the non-modified emulsion polymerisation at normal temperatures and leading to cold rubber obtained by means of modifiers, redox activation and temperature reduction, hold out hopes that these problems, too, will be solved in the future.

Control Installation of North-West Pipeline

The North-West Oil Pipeline from Wilhelmshaven to Cologne (see THE ENGINEER, February 27, page 356) which has a length of nearly 400km is unusual in that it serves a number of different petroleum undertakings and refineries. Its operation is therefore rather more complex than that of an ordinary pipeline which merely connects, say, an oilfield with a port.

The pipeline is remote-controlled from a central station (illustrated) at Wilhelmshaven, whence the various consignments, each amounting to several thousand tonnes, are despatched in sequence and directed to their destinations. Since mixing is only slight it can be neglected so that there is no need to use a go-devil for separating the different grades. On the other hand, it is necessary to measure the density of the liquid in the pipe, since it is this which indicates when a batch has passed and a new batch arrives. The pumping speed is an inadequate criterion because it is affected by local differences in temperature, &c. Measurements of pressure in the different sections of the line must also be available to the central control.

For density measurements use is made of a mechanical density balance the pyknometer of which is constantly kept filled with oil by a pump. The balance acts upon the resistance of a transducer, so that readings of density are transmitted as electrical quantities. Pressure measurements are also converted into electrical readings,



Central control panel with diagrammatic representation of the main pipeline and branch lines to refineries

use being made of Bourdon tubes to which strain gauges are connected.

For transmission the pulse frequency method is employed in which the quantity to be measured is expressed by a series of pulses. An electronic pulse generator changes the d.c. output from

the transducer into a frequency of the order of five to fifteen pulses per second which are sent out over a transmission line. In the receiver, a polarised relay alternately charges and discharges two condensers ; the resulting direct current which is continuously recorded is proportional to the pulse frequency and hence to the value of the original measurement.

Control pulses and signals are transmitted by the so-called pulse-code method which permits multiple exploitation of the transmission channels. Correct transmission is assured by following each command or signal code by the same code in reverse. Only after the accuracy of the transmission has been established by automatically checking the first against the second message, does a command take effect. Signals can be called for from the central control point, using the same transmission lines. In this way, valves can be opened or shut, and the degree of opening can be indicated to the controller.

Signals from the substations to the control room serve to report breakdowns in pumping stations, excessive pressures, and the passage of the go-devil which is sent through the line periodically to clean it.

In order to protect the pipeline, a safety disc is fitted in each branch ; the disc fractures under excessive pressure and releases the oil into a special tank of several hundred cubic metres capacity. At the same time, the fact that the disc has fractured is indicated on the control panel.

The pulse-code installation makes use of audio-frequency channels in post-office telephone lines leased for this purpose. Intervals between adjacent channels amount to 120 c/s. The network comprises two trunk lines, from Wilhelmshaven to Bersenbrück and Wesel with four branches from each of these centres ; and from Wilhelmshaven to Düsseldorf ; from there five other branches radiate to neighbouring installations. The total number of channels going out from Wilhelmshaven is thirteen, that of incoming channels is thirty-five. The telephone lines are also used for teleprinter transmissions which are received at all the stations simultaneously irrespective of the origin of the message. In addition there is a telephone system with automatic dialling for 100 extensions.

In designing the control systems for the North-West Pipeline, the firm responsible for this part of the work, Siemens and Halske A.G., aimed at a simple and unified system in order to facilitate maintenance and repairs. The individual units of the pulse-code installation have the form of plug-in panels, and two voltage-controlled mains units as well as a battery for emergency use are available. The impulse frequency telemeter instruments and audio-frequency control currents are operated with current obtained directly from the a.c. mains.

Combined Guillotine and Press Brake

We illustrate a combined guillotine and press brake which has been developed by Wieger Maschinenbau G.m.b.H., Neuss/Rhein, Germany, particularly for use in small and medium-sized factories where space limitations and limited work capacity makes the installation of two separate machines uneconomic. This machine has a base of conventional welded plate construction incorporating a table to the back of which is fixed the lower guillotine blade. When the machine is to be used as a press brake the lower forming tool is mounted on the table above the blade level. The upper guillotine blade and the press brake tooling and hold-down assembly are mounted one on each side of a beam. This beam is trunnion mounted in the main side arms and it is swung through 90 deg. by a geared motor to bring either the guillotine or the press brake tooling into the operative position in relation to the table. When in the required operative position, the beam is rigidly locked to the side arms by heavy combined stud bolts and locating pins.

The beam and arm assembly is pivoted at the rear to the machine and near the front is coupled by rods at each end to the main driving shaft in the base. This shaft is driven by motor through a multi-disc clutch designed to give single-stroking of the beam assembly under pedal control and ensure that the beam is automatically stopped at top dead centre between strokes. Spring-loaded levers are used to guide the beam assembly and, as can be seen in the illustrations, no conventional fixed side guide uprights are fitted. As with other machines made by the firm, the arc through which the upper guillotine blade moves in the cutting operation is used to give a small, progressively increasing, clearance between the blades directly after they have parted the metal. This method of cutting eliminates need for blade clearance adjustment and makes it possible to shear very light gauge sheet into narrow strips without distortion or buckling of either the stock or the strips.

It is claimed that the machine can be adapted from one form to another in five to ten minutes, and at the recent European Machine Tool Exhibition in Paris we were shown that this could be done with ease. The machine can be fitted with a special tooling for punching work to the end of the table.

These machines are made in four models—two with capacities of 50 tons and two of 80 tons, and the particulars we give below are those for the smallest model with the corresponding figures for the heaviest machine in brackets. When arranged as a guillotine, a 2000mm (3000mm) length of cut can be made and material up to 2500mm (3500mm) wide can pass through the machine between the side arms. With sheet material of 45 kg per square millimetre thicknesses up to 6mm (7mm) can be cut. When the press brake equipment is in use, the working length is 2150mm (3000mm) and a height of stroke 70mm (75mm) is available with a ram adjustment of 100mm (125mm). With the punching equipment, a maximum pressure of 25 tonnes (40 tonnes) is available with a similar height of stroke and length of ram adjustment to the press brake. All the machines are designed for speeds up to thirty strokes per minute.

Third International Symposium on "Hardness Testing in Theory and Practice"

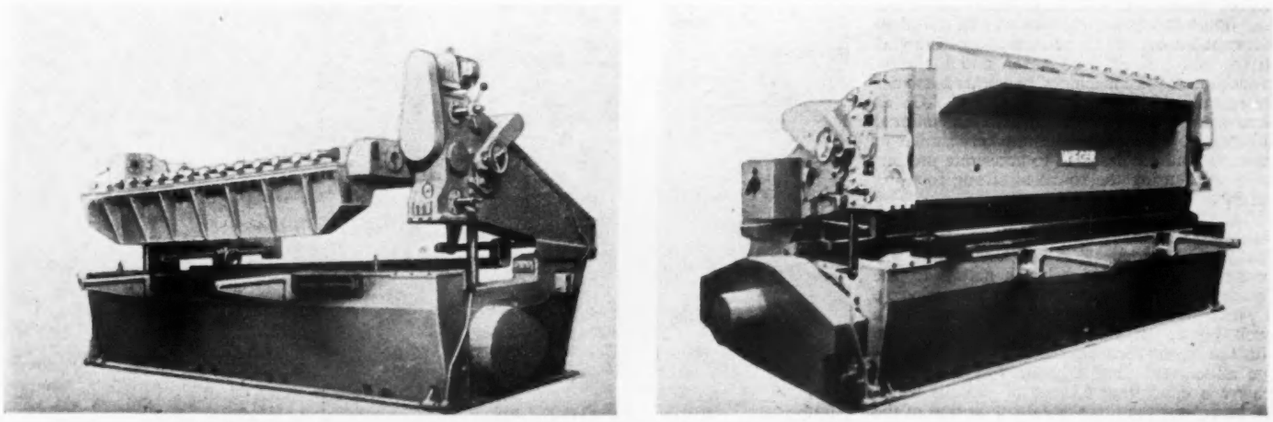
The Third International Symposium on Hardness Testing will be held in Dortmund from September 23 to 25, 1959, under the auspices of Verein Deutscher Ingenieure, Düsseldorf, and the Staatliches Materialpruefungsamt. This is a continuation of the two international Symposia on the same subject held in Bremen in 1952 and in 1955 respectively, its object being to show the recent progress that has been made in this important field of material testing and production control.

Starting from fundamental considerations of the trends in the testing of materials and of the physical basis of hardness determinations, specific applications and difficulties in Vickers hardness testing with small loads and with micro-loads will be discussed and *inter alia* the general question of non-destructive measurement of the thickness of deposits, of diffusion zones, the effect of micro structure and grain size on elastic recovery and piling-up will be dealt with. The present state of micro-hardness testing in the U.S.A. will be reviewed, including new principles for the design of hardness testing apparatus. There will be a report on the present position of hardness testing research in Japan. Special problems to be considered include the hardness testing of balls, sheet, and thin steel strip. A further report will deal with the relationship between Vickers hardness and the yield point of aluminium, copper and steel. The determination of the depth of case hardening will be dealt with and a modified design of diamond indenter will be described.

The last day of the congress will be devoted to a number of short papers concerned with problems that arise in the comparison and standardisation of Rockwell, Brinell, Vickers and Shore hardness testing machines. In particular, reference will be made to inherent errors, methods of examining the tips of indenters, the use of statistical methods in hardness testing, and the preparation of standard hardness test blocks of small load and micro-hardness testing. In addition to the German contribution there will be papers from France, U.S.A., Italy, Sweden, Japan and Russia.

Italian Airliner

The first four-engined passenger airliner built in Italy since the war recently passed successful flight tests. Designed by Filippo Zappata, the aircraft, known as the "A.Z.87" is to be series produced by the Augusta Aircraft Works in Gallarate (Lombardy). The principal data of the "A.Z.87" are stated to be : power plant, four Alvis-Leonides 540 h.p. engines ; total weight, 11,300 kg ; cruising speed, 400km per hour ; range, 2000 km ; number of passengers carried, twenty-six.



Combined guillotine and press brake in guillotine setting (left) and with beam being swung through 180 deg. to bring press brake into position (right)

Zero Gradient Synchrotron at the Argonne National Laboratory

BY OUR AMERICAN EDITOR

The construction of a giant, doughnut-shaped particle accelerator recently began at the Argonne National Laboratory at Lemont, Illinois. At the request of the U.S. Atomic Energy Commission, Congress authorised the design and construction of the machine, which is called the Zero Gradient Synchrotron (ZGS). Its estimated cost is 29,000,000 dollars. It is anticipated that the availability of this machine will help to make the Midwest of the U.S.A. a future centre for high-energy physics studies. The ZGS will be housed in a ring-shaped building 200ft in diameter, containing a large magnet arranged in eight sections around the outside of a circle. In operation, protons will first be accelerated to 800kV by a standard high-voltage source. From there they will go into a linear accelerator, attaining 50 MeV. Finally, they will be introduced into the ZGS in short, well-regulated bursts, causing acceleration to 12,500 MeV in one second.

THE Argonne National Laboratory is now constructing on its site at Lemont, Illinois, a proton synchrotron which will accelerate protons to an energy of 12·5 BeV. (In accordance with the U.S. concept of a "billion," 1 Bev=1000 MeV.) This instrument will be used to study the properties of fundamental particles and the behaviour of the so-called strange particles. It has been established, principally at the Ernest O. Lawrence Radiation Laboratory, at the University of California at Berkeley, and also at the Brookhaven National Laboratory, that when protons of such high energy come into collision with other protons at rest, then a variety of phenomena occur, such as the production of many particles which have very short lives of, say, 100 millionth of a second. Several varieties of these particles are already known, including π mesons, K mesons, λ hyperons and Σ hyperons. In addition to this, it is also possible to produce anti-protons and anti-neutrons if the energy of the collision of the primary particles is above 5 BeV.

To understand the importance of the machine which is being constructed at the Argonne National Laboratory, it is appropriate to review the existing machines in the world to-day. First, at the Brookhaven National Laboratory, there is the Cosmotron which is a proton synchrotron accelerating protons to 3 BeV. This machine can produce many of the "strange" particles but does not have a sufficiently high energy to produce anti-protons or anti-hyperons. At the University of California there is the Bevatron which can accelerate protons to 6·3 BeV. With this machine it is just possible to produce anti-protons and some of the anti-hyperons, but it is not possible to produce all the anti-hyperons which are believed to exist. In the U.S.S.R. there exists the "Big Volga" synchrotron which can accelerate protons to 10 BeV. In principle, this machine can produce all presently-known particles. From recently received reports, it is believed that this machine is not operating with a sufficiently high beam intensity to be able to perform decisive experiments; however, it is to be expected that in the near future the beam intensity will be raised so that experiments can be performed as readily as on the machines at Brookhaven and Berkeley. In addition to these machines, two other machines are nearing completion*: the CERN AGS at Geneva and the AGS at the Brookhaven National Laboratory. These machines are very similar in character and are designed to accelerate protons to 25 BeV, using the so-called strong focusing principle.

The Argonne machine differs from the Brookhaven AGS in many important respects. Principally, the Argonne ZGS machine is a weak-focusing machine comparable in nature to the Cosmotron and Bevatron. Using this principle of weak-focusing, it is possible to achieve a much higher circulating beam intensity than with the strong-focusing machine. It is therefore anticipated that Argonne will be able to achieve a circulating current of protons which will be at least ten times as intense as that of the Brookhaven or Geneva machines. It may therefore be said that these machines are complementary in character. The Brookhaven and Geneva machines will have a higher energy than the Argonne machine, but the latter will have a much higher beam intensity. It is to be expected, therefore, that those experiments involving very rare occurrences would be more easily performed on the Argonne machine than anywhere else, whereas those experiments requiring the highest possible energy would be performed on the higher energy machines.

* Another machine under construction is the weak-focusing 7 BeV proton synchrotron at the Rutherford High Energy Laboratory, Harwell, England. It is due to be completed in 1961.

Design of Accelerator

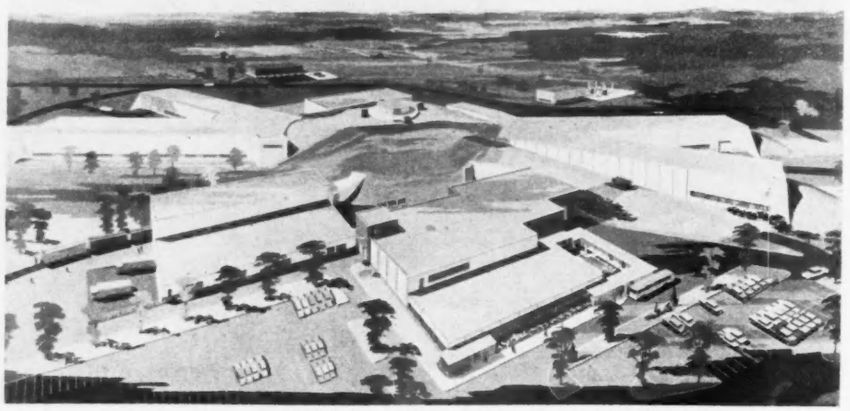
The ZGS proton synchrotron is a very complex device of advanced design, utilising many new principles in its construction. An indication of the complexity of this accelerator can be obtained by reference to the illustration opposite. Protons from a conventional ion source are first accelerated to 800kV with a standard high-voltage supply. They are then accelerated to 50 MeV by passing through a linear accelerator which consists essentially of a resonant cavity operated at 200 Mc/s, and containing 124 drift tubes, each containing a focusing magnet. By the aid of a system of magnets, drift tubes and cavities, the protons are accelerated from 800kV to 50 MeV and are maintained in a well-focused beam only a few millimetres in diameter. The protons are then conducted by means of a series of bending and focusing magnets into the synchrotron magnet itself.

The synchrotron magnet is arranged in eight sections or octants around the circumference of the circle, whose diameter is about 200ft. This magnet is of the window-frame construction which achieves magnetic field strengths up to 21,500 gauss. It is this factor which enables Argonne to construct a weak-focusing machine at such a high energy as 12,500 MeV. When the 50 MeV protons are injected into the synchrotron magnet, the magnetic field is very low, about 500 gauss. The magnetic field is raised to its maximum value of 21,500 gauss in one second. At the same time, the protons are accelerated each time they circulate around the machine on their passage through a high-frequency cavity. This r.f. cavity is constructed in such a way that its frequency and voltage can be controlled. Thus, the energy of the particle is increased in step with the magnetic field so that the orbit of the particle remains within the synchrotron magnet.

Upon attaining the maximum energy of 12·5 BeV, or at any time before this, the high-energy protons can be removed from the machine into an experimental area. This extraction process can be achieved with the aid of a system devised at Brookhaven by Dr. O. Piccioni. The system is based on allowing the protons to traverse a target of some material such as copper or beryllium. This decreases the energy of the particle slightly and reduces the radius of curvature of the particles in the magnetic field. In this way, the particles can be made to enter a deflecting magnet and be deflected out of the synchrotron. The particles will then be controlled with the aid of bending and focusing magnets so as to provide a well-collimated beam of protons in an experimental area. This system of targets and magnets can be duplicated so as to achieve two separate and simultaneous proton beams in two experimental areas. It is this ability of the ZGS to provide very high intensity external beams of protons at 12·5 BeV which will distinguish the Argonne accelerator. At the present time, no similar scheme has been successfully demonstrated on a strong-focusing accelerator. In addition to these two experimental areas where protons can be used as the primary beam, there is a so-called meson area. This is a large room of 100ft by 200ft separated from the synchrotron itself by a steel wall which will be about 12ft thick, 60ft long and 15ft high. This wall will weigh about 5000 tons and will be pierced with holes. Through these holes will come the secondary particles emanating from targets placed in the circulating high energy proton beam. These secondary beams of particles will consist of scattered protons, various kinds of mesons and anti-protons. Because of the high intensity of the circulating beam, it is expected that these beams of secondary particles will be the most intense beams obtainable anywhere in the world.

Accelerator Injector System

As previously mentioned, the pre-accelerator consists of an 800kV d.c. supply and a 50 MeV linear accelerator. The 800kV supply will be situated in a high bay close to the main office building. This 800kV pre-accelerator will be of conventional design, as presently used in conducting research in low-energy nuclear physics. It will, however, be designed for pulsed rather than continuous operation. This is necessary



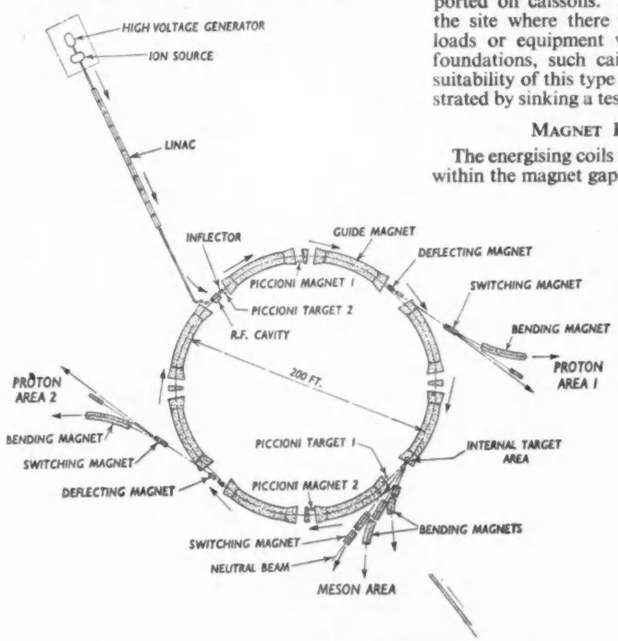
Architect's drawing of Zero Gradient Synchrotron (ZGS) buildings

because the machine itself is pulsed and also because the 50 MeV accelerator must be pulsed.

The linear accelerator consists of a resonant cavity about 37in in diameter and 110ft long; r.f. power is fed into this accelerator with a frequency of 200 Mc/s and at a very high power level. It is anticipated that the cavity will be supplied with a pulsed r.f. power of about 5MW peak power. Within this cavity are situated 124 drift tubes, each of which is individually designed and manufactured with very close machining tolerances. Within each of these drift tubes is a focusing magnet which, again, must be manufactured and assembled within very small tolerances. The whole linear accelerator is mounted on a very stable foundation and maintained at a constant temperature. It has been calculated that if a deflection of as much as 0·001in were to occur, the linear accelerator would no longer be able to operate efficiently.

Design of Magnet

There are, roughly speaking, two different kinds of high-energy proton synchrotrons which can be built. These are the strong-focusing and weak-focusing machines. The weak-focusing



General arrangement of the 12·5 BeV Zero Gradient Synchrotron at the Argonne National Laboratory

machines, such as the Cosmotron and Bevatron, have a magnetic field which is almost uniform but because of the weak-focusing nature a large air gap in the magnet is required. This causes the magnet to be rather large. On the other hand, the strong-focusing machines utilise a magnetic field which has a very sharp gradient, and by alternating the gradient it is possible to design a machine which has a rather small air gap and, therefore, the magnet becomes small. The advantages of this system can be demonstrated by pointing out that the Russian synchrotron, which is a weak-focusing machine at 10 BeV, has a magnet which weighs 36,000 tons, whereas the AGS machine with an energy of 25 BeV has a magnet which weighs only 4000 tons. The economy of the latter design is apparent.

However, in a weak-focusing machine, because of the large aperture, it is possible to inject a large number of particles into the machine, whereas with a strong-focusing machine it is not possible to do this. One has, therefore, to balance intensity and economy. Prior to the design of the ZGS machine at Argonne, it had not been possible to design an efficient synchrotron magnet which had a magnetic field in excess of about 14 kilogauss. This also is a serious economic factor because the higher the magnetic field that one can achieve the smaller will be the diameter of the machine, and therefore the smaller will be the amount of iron in the magnet.

The window-frame construction which is being used on the ZGS and which was suggested and built by Dr. Martyn Foss, enables magnetic fields as high as 21,500 gauss to be achieved. In this way the diameter of the magnet is considerably reduced, and the magnet will weigh only about 4000 tons. The magnet is designed to have a uniform magnetic field and the control and focusing of the particles is achieved by arranging the edge of the magnet sections at an angle to the orbit of the particles. The fact that the magnet has a uniform field is the reason for the choice of the name Zero Gradient Synchrotron.

The behaviour of the synchrotron depends on maintaining the eight sections of the magnet in very careful alignment with one another. To achieve a high degree of stability of the magnet, it will be supported on caissons. These are 39in diameter concrete pillars which are sunk 90ft in the ground down to bed rock. In this way the magnet is directly supported upon the bed rock, which in this region is one of the most stable foundations in the U.S.A. To provide the same kind of stability, the linear accelerator is supported on caissons. At various points around the site where there will be either very heavy loads or equipment which requires very stable foundations, such caissons will be used. The suitability of this type of foundation was demonstrated by sinking a test caisson last November.

Magnet Power Supply

The energising coils for the magnet are situated within the magnet gap and consist of thirty turns of copper rod of rectangular cross-section with a circular hole down the rod through which cooling water can pass. In order to make the magnetic field rise from 0 to 21,500 gauss in one second, it is necessary to have a very large motor-generator set. The pulse of current is initiated by applying 12,000V to the coil of the magnet, causing the current to rise in such a fashion that the peak current will be about 11,000A after one second, and will enable the peak magnetic field to be attained.

The magnitude of the equipment can be appreciated from the following figures. The peak power supplied to the magnet will be 100,000kVA. The maximum stored energy in the magnet is 41,000,000 joules, and carrying out the full magnetic cycle of allowing the magnetic field to remain at its highest value for 0·3 of a second and then return to 0 within a few seconds and then repeat the whole cycle every four seconds, the maximum dissipated power in the magnet will be 6·9MW. It can be seen then that this power supply is an unusually large one and is subject to the unusual conditions of having to yield a very large amount of power every four seconds with a quiet period between. To smooth out the absorption of the power from the main supply lines, it is necessary to use a flywheel system to store energy. Although no accurate figures can be given, because the system is not yet under contract with a manufacturer, it is anticipated that there will be motors of approximately 15,000 h.p. which will drive a flywheel weighing about 150 tons, which is to be coupled directly to an a.c. generator. This generator is then connected in turn to multi-winding transformers and mercury-arc rectifiers. After rectification, power is fed directly to the magnet. Therefore, when a current pulse is initiated, energy is taken from the flywheel, which slows down correspondingly this energy being fed into the magnet. At the end of the magnet cycle when the magnetic field is decreasing, the stored energy in the magnet is fed back into the flywheel to speed it up again. It is expected that the speed of the flywheel will decrease by about 6 per cent.

It should be mentioned that there will be a very severe cooling problem in the magnet. It will be appreciated that the coil which carries the current in the magnet is subject to very severe stresses produced by these very large pulses of power and very high magnetic fields. The most satisfactory way to prevent damage to the coil is to secure it firmly. However, one must consider the problem of thermal expansion. Each of these coils is 53ft long and is embedded in the magnet. To avoid damage from differential thermal expansion, the temperature of the coils and that of the magnet must be held practically constant at all times. The cooling system for the magnet must be designed accordingly so that even with the generator turned off completely, the magnet and the coils are always maintained at 80 deg. Fah. When the magnet is pulsed, the cooling supply is increased and will be such that the temperature should rise only 6 deg. Fah. during a single pulse.

High Vacuum System

To achieve the successful operation of the accelerator it is essential to have a high vacuum in the interior of the magnet and between the magnet sections. For the best results this vacuum must be better than 2×10^{-6}mm Hg. Such a high vacuum can be achieved with the aid of sixteen 32in diameter oil diffusion pumps with suitable mechanical rough vacuum pumps assisting them. Such a vacuum system is of a conventional character and should not pose any problems in construction or operation. However, the design of the vacuum chamber itself does involve some novel aspects. As discussed previously, the synchrotron magnet is not of conventional design and the region which must be evacuated is 32in wide by 5½in high and is totally enclosed by the magnet and the magnet coils. If one were to attempt to build a vacuum box to be inserted in this space one would find that the box would have to be about 2in thick to withstand the air pressure. Such a thickness would seriously reduce the available space for the acceleration of particles. On the other hand, if one were to increase the gap in the magnet in order to accommodate a box with reasonable interior dimensions, then the size of the magnet and the magnet power supply would increase enormously and would cost many millions of dollars extra.

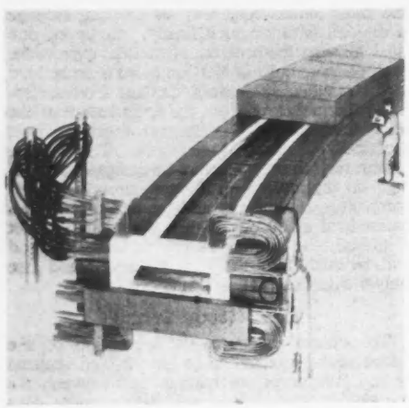
To overcome this problem Argonne is designing a double vacuum chamber. The outer vacuum chamber will consist of the magnet itself suitably sealed and capable of being evacuated to a pressure of less than a small fraction of a millimetre of mercury. Inside this so-called rough vacuum chamber there will be a thin-walled inner vacuum chamber constructed of thin sheets of stainless steel (the most suitable material because it combines non-magnetic properties and high electrical resistivity). Because the magnet is pulsed, a metallic object placed in the magnetic field will have large circulating currents induced in it. These currents tend to upset the carefully designed magnetic field shape and could even prevent the operation of the synchrotron. Such effects are minimised by making necessary metal parts from materials of high resistivity.

Calculations show that with a thin stainless steel inner vacuum chamber the problem will not be serious. It should be possible to evacuate the interior of the inner vacuum chamber to the low pressures indicated previously. Of course, precautions will have to be taken to prevent the rupture of this inner vacuum chamber. In particular, when evacuating the two chambers the pressure on both sides of the inner vacuum chamber must be kept very nearly equal at all times.

Radio Frequency System

The r.f. system consists of two tuned cavities situated side by side in one of the field-free regions between magnetic octants. These cavities are excited with r.f. power so that they develop about 20kV across a gap, and it is this voltage which accelerates the protons as they circulate around the synchrotron. It is necessary for the frequency of these cavities to be variable from 4 Mc/s and for the voltage to be

adjustable. The variation in frequency is necessitated by the fact that the time taken for a 50 MeV proton to circulate around the synchrotron at low magnetic field is very different from the time taken for a 12·5 BeV proton to go around the machine at high magnetic fields. As the r.f. system must keep the particles in step



Magnet octant showing coil assembly and vacuum chamber

with the magnetic field it follows that the frequency of the cavities must be closely controlled and must very closely track the magnetic field.

This variation of frequency is accomplished by loading the cavities with ferrite, a magnetic material which is capable of operating at high frequency and has properties that can be controlled with the aid of a d.c. bias current. By carefully adjusting the bias current, the frequency of oscillation of the cavities can be adjusted. The close control of the circulating particles by the r.f. system is an essential part of the synchrotron and is the method by which the circulating protons can be forced on to a target to produce mesons or an absorber to produce an external proton beam. The magnitude of the problem can be appreciated by the fact that the frequency of the r.f. system must be controlled at all times to 0·03 per cent.

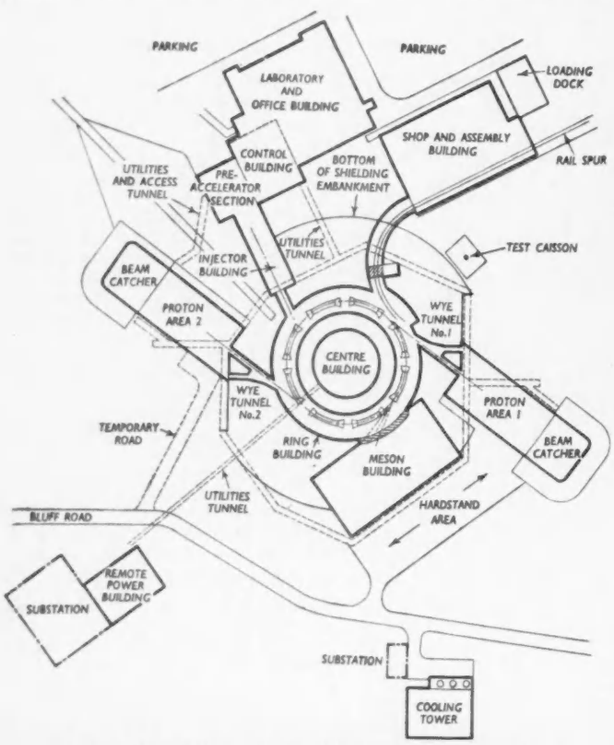
Building Design

The ZGS project will be one of the largest projects on the Lemont site, and it is estimated that well over 100 people will be required merely to maintain and operate the machine. Consequently, the project involves the construction of a self-contained unit complete with all necessary office and laboratory facilities. The synchrotron itself will be housed in a ring-shaped building approximately 30ft square in cross section and 200ft in diameter. In the centre of this "doughnut" there will be another building, approximately 90ft in diameter and 50ft high and containing four floors of equipment. The ring building will be covered with a mound of earth with a minimum thickness of 20ft and extend about 100ft away from the ring building. This unit will therefore appear as a mound of earth 400ft in diameter at the base, rising to a height of 50ft and about 200ft in diameter at the top. To provide access to the centre building, a roadway will run up the mound of earth, with a circular road on the top.

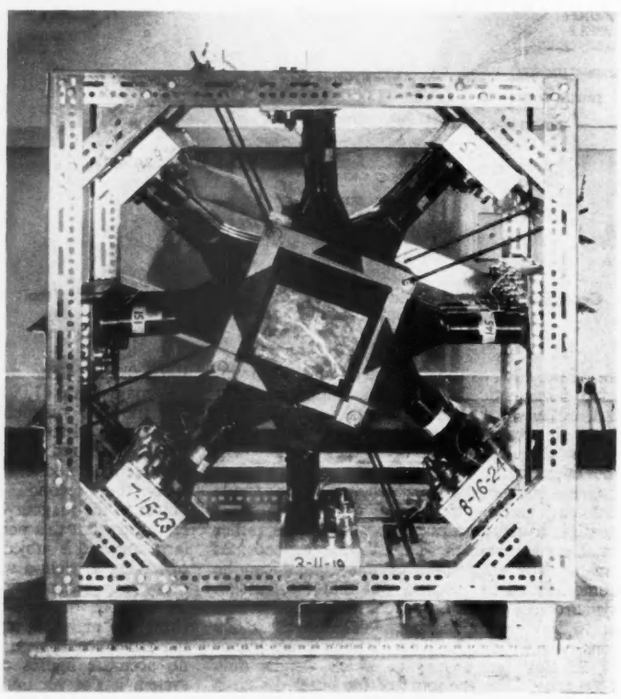
The linear accelerator will be housed in a building about 120ft long which will also be covered with a mound of earth. The earth shielding described above will serve to reduce the radiation level outside the machine to a tolerable level. When the machine is in operation the radiation level within the ring building will be much higher than can be tolerated by human beings. Consequently, no one will be allowed in the ring building when the machine is in operation, but the shielding provided by the concrete walls of the ring building and the mound of earth over it will be adequate for the protection of personnel in other areas. The experimental areas are, of course, close to the machine. The meson area will be a building 100ft wide and 200ft long with a 35-ton crane servicing the whole area. As it is anticipated that large quantities of shielding in the form of concrete blocks and steel blocks will be needed by experimentalists in this area, the floor is being designed to withstand a floor load of 3 tons per square foot over the whole area. This experimental area will be separated from the machine by a steel wall. This steel wall will be constructed of surplus armour plate steel allocated to Argonne by the U.S. Navy. This armour plate originally was intended for the repair of various battleships.

Because many experiments are expected to require much longer distances than the dimensions of the meson building, there will be provided outside the building an area of hardstand construction so that, if necessary, experiments can be set up outdoors to utilise some of the advantages that large distances will bring. The two proton areas will initially be merely concrete floor pads with no buildings over them. However, future needs probably will require that these areas be extended, covered with buildings and provided with cranes and other facilities. It is also believed that the use of the proton beams will require the construction of target stations. These are envisaged at present as being blocks of steel weighing approximately 1000 tons, with channels cut through them so that the proton beam can pass through, strike a target in the interior, and secondary particles can emerge through the channels provided. Owing to the large weight of these target stations, caissons will be sunk at selected points to sustain this weight. The main control room for the synchrotron will be situated at the head of the linear accelerator building. It will be contained in the laboratory and office building which will be the headquarters of the maintenance and operating staff of the synchrotron.

Adjacent to the laboratory and office building will be another structure, the shop and assembly building, which will be used in the initial stages of the construction of the machine for the receipt of the components of the synchrotron and their evaluation and testing. Later, when the machine is in operation, this building will be used to construct the large pieces of experimental equipment which will be necessary in order to perform experiments with the synchrotron. Contained within this building will be the main stock room and machine shop for the site. There will also be one other large building, the power building, situated south of the ring building and housing the motor-generator set which provides the energising power for the synchrotron magnet. This building will adjoin the substation into which comes the power from the Public Service Company of Northern Illinois and will be close to the cooling tower which will provide cooling water for the whole complex of buildings.



General plan of the synchrotron buildings at the Lemont site



Stack of twenty-four square scintillation counters for the detection of the decay of neutral particles

Synchrotron Applications

At the present time, there is no machine at the Argonne National Laboratory capable of producing any particle discovered within the last twenty-five years, and no machine in the entire Midwest can produce the "strange" particles discovered in the last ten years. The physicists at the universities of the Midwest must go to distant laboratories to pursue research on such

particles or are forced to abandon the work altogether. Moreover, when the U.S. Atomic Energy Commission asked the Argonne National Laboratory to build a machine of conventional design in the 10–15 BeV energy range, it was understood that this facility was needed to fill an intolerable gap in the country's scientific programme. In order to fill this gap and enable Midwestern universities to attract and keep scholars in the field of high-energy physics, Argonne is now moving with all possible speed to complete the construction of this vitally-needed machine.

The Argonne machine will carry out two related functions : (1) it will be a source of particles. (2) It will serve as a " microscope " for examining sub-nuclear systems. As a source of particles, it will be used to produce all of the thirty known or anticipated particles. Of all these particles, only three are commonly found as stable particles in nature. The heavier a particle is, the more energy is required to produce it, and in order to make heavy anti-particles, very large energies are required. With the highest energy machines now operating it is possible to make small numbers of anti-protons, anti-neutrons and hyperons (unstable particles heavier than the neutron). The Argonne ZGS is expected to produce these particles in abundance. At this time, the direct evidence for the existence of anti-hyperons rests on a single observation, but indirect evidence strongly indicates that five other anti-hyperons exist. The Argonne machine should be able to produce all six of the anti-hyperons in quantity. It may also happen that new particles will be discovered for which there is yet no evidence of any kind.

In its part as a " microscope," the ZGS will produce particle beams for use in exploring the behaviour of the particles when they interact at very short distances. This will give information about the structure of the individual particles and about the laws of force governing their interactions. There are several kinds of forces, such as gravitational forces, electromagnetic forces, the " strong " coupling forces which bind the atomic nucleus, and the " weak " coupling forces which govern the decay of neutrons and many of the other particles. By studying the interaction of all the particles Argonne hopes to discover when these forces apply and whether there are other types of forces which thus far have escaped notice.

Particle Detection

All experiments carried out on large particle accelerators require some means of detecting the particles which have been produced by these machines. This detection may involve determining whether or not a particle was at a certain place at a certain time, or it may consist of a more elaborate arrangement to measure velocities, or energies, or some physical property of the particles such as mass or magnetic moment. Since these particles are very small indeed and since they have velocities very close to the velocity of light as they emerge from the accelerator, this problem of detection is not a simple one. There are many different methods of particle detection used, and the choice of method is ordinarily dictated by the particular experiment being performed. The methods can be divided very roughly into two classes : those associated with some kind of electronic circuitry and those that involve photographic technique. The three types of detector whose output is usually electronically recorded are the ionisation counter, the scintillation counter and the Cerenkov counter. Photographic methods are used either directly, by exposing photographic emulsions to beams of particles, or more indirectly in connection with cloud chambers and bubble chambers.

Ionisation Counters.—In its simplest form, the ionisation counter consists of a gas-filled cylinder with a fine wire through its axis. This wire is maintained at a high positive voltage. When charged particles or gamma rays enter the cylinder, they ionise the atoms. These negatively charged electrons are strongly attracted to the positive wire and move rapidly towards it, colliding with other electrons as they move and freeing them. They in turn free other electrons, and, in a very short time, this " avalanche " of electrons collects on the central wire, forming a measurable electric pulse.

There are many varieties of ionisation counter ; the Geiger counter is probably the most familiar of these. Ionisation counters are most often used to determine the kind, strength and quantity of radiations from a given source. At the ZGS, they will probably be used primarily to check radiation levels around the machine and in experimental areas, although many experiments will use them directly as a part of the experimental apparatus to detect and measure the properties of particles.

Scintillation Counters. — The scintillation counter has two main parts : the scintillating material itself and a photo-multiplier tube to detect and amplify the scintillations. When a charged particle passes through the special scintillating material, it loses a very small amount of its energy to the atoms of the material which are near the path of the particle. This energy is then re-radiated by the atoms in the form of visible light. The very small amount of light produced is detected and amplified by the photo-multiplier tube and made to produce an electronic signal.

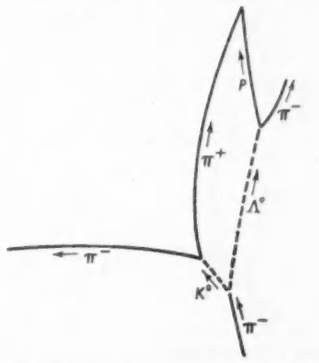
This type of detector has the advantage that the amount of light collected by the photo-tube is proportional to the energy lost by the particle as it passes through the scintillator, and a direct determination of particle energies can often be made using this method. It is hoped that it will soon be possible to construct a scintillation detector whose output of light can be amplified enough to be photographed. This type of detection would then be quite similar to cloud chamber and bubble chamber detection.

Cerenkov Counters.—The Cerenkov counter, like the scintillation counter, produces a pulse of light when a high-energy charged particle passes through it, and this light can be detected by a photo-multiplier tube. Cerenkov radiation is produced when a particle moves through a material with a velocity which is faster than the velocity of light in that material. It is very similar to the shock wave created by an aircraft when its velocity exceeds the velocity of sound in air, or to the bow wave of a boat moving through water. Like the bow wave from a boat the Cerenkov " wave " emerges at an angle from the particle trajectory and, as in the case of the water wave, this angle is dependent upon the velocity of the particle. Within certain limits, quite accurate determinations of velocities can be obtained using Cerenkov counters, and when the latter are combined with scintillation counters, much information can be obtained about the particles which traverse the detection system.

The photographic methods of particle detection are all considerably slower than electronic methods. Particles are somehow caused to form tracks, either directly in an emulsion, or in some material which can be photographed. These tracks must first be found by careful scanning of the emulsion or film. They are then measured in various ways, and finally the measurements are analysed and interpreted. This process takes time, but in many cases offers considerable advantage over electronic methods, the greatest of which is the ability actually to " see " the collisions or other events which have taken place. In some cases, the property of integrating or collecting events for a considerable period of time is important.

Photographic Emulsions.—Photographic emulsions used in detecting particles are nothing more than thick photographic films which are sensitive to high energy charged particles rather than to visible light. The emulsions can be placed directly in the beam of high-energy particles from accelerators and whenever one of these particles passes through the emulsion, it leaves a track which will appear when the emulsion is developed. The importance of this is that the high energy particles often collide with atoms of the emulsion, causing them to split up into other particles, most of which will again leave tracks. To find and identify these " events," the photographic emulsion is scanned under a microscope, careful measurements of angles and lengths of track are made, and from these, energies and masses can be determined. Photographic emulsions have been of great importance in the discovery of new particles and in the measurement of their properties.

Cloud Chambers.—The cloud chamber consists of a windowed container within which is a super-saturated vapour. When a charged particle passes through the chamber, it frees electrons from the atoms in the vapour along its path just as in the case of the ionisation counter. In the cloud chamber, however, tiny droplets of the vapour condense on these ionised atoms and they form a visible track along the path of the particle. If the particle has collided with one of the particles which make up the vapour in the chamber, this too will be visible, and these " events " are, usually, of interest to the physicist. The tracks can be photographed, and measurements are then made on the projection of the photographic film. A magnetic field is also provided to cause the charged particles to curve as they pass through the chamber. Measurements of this curvature as well as measurements of angles between tracks can be made and thus the masses and moments of the particles involved in these events can be determined.



Schematic drawing of actual reactions which occur in the bubble chamber

Bubble Chambers.—The bubble chamber is the most recent addition to the family of particle detectors. It consists of a windowed chamber, like the cloud chamber, but filled with a liquid such as liquid hydrogen. This liquid is " superheated " at a particular temperature and pressure. Hence, it is at a temperature higher than its boiling point but will not actually boil until some impurity or disturbance is introduced. The high-energy charged particles from accelerators provide such a disturbance, and tiny bubbles form as they pass through the liquid. If a photograph is taken just after a particle has traversed the chamber, these bubbles will appear as a track along the actual path of the particle. Just as in the cloud chambers, the collisions with atoms of the liquid are the events of interest, and they show up very plainly on the photograph. Since liquid has a much higher density than vapour, there is a larger target area presented to the particles passing through and the probability of collisions occurring is greater than in the cloud chamber. Again a magnetic field is provided to cause the path of the particles to curve. The illustration above gives an example of the production and disintegration of sub-atomic particles. The " event " shown schematically is the associated production of " strange " particles by a negative π meson interacting with a proton in a hydrogen bubble chamber. The actual reactions which occurred in the bubble chamber were : A π meson is captured by one of the protons in the hydrogen, which then decays into a K° meson and a Λ° hyperon. The K° decays into a π^+ and a π^- meson, while the Λ° decays into a proton and a π^- meson.

The photographs from cloud chambers and bubble chambers are scanned for events, and measurements of these events are made, usually by projecting the photographs on to a specially built table which permits measurements to be made semi-automatically. These measurements are so complex that they ordinarily must be analysed by an electronic computer. The analysis of bubble chamber photographs at the ZGS will be done on one of the Argonne National Laboratory's large electronic computers.

Personal and Business

Appointments

MR. KENNETH RONEY has been appointed technical press officer of the National Coal Board.

DR. O. P. HANSOM has been appointed technical director of Carter Thermal Industries, Ltd.

MR. L. B. DEVINS has been appointed general manager of Sheffield Wire Rope Company, Ltd.

MR. P. E. JACKSON has been appointed technical sales engineer, South Wales Area, for Erskine, Heap and Co., Ltd.

SIR JOHN PASCOE has accepted an invitation to join the board of the Timken Roller Bearing Company of Canton, Ohio.

MR. R. J. WRIGHT has been appointed a director of Lincoln Electric Company, Ltd. He will continue as export sales manager.

ATOMIC POWER CONSTRUCTIONS, Ltd., has announced that Mr. J. W. Ashley has been elected to the board as technical director.

MR. B. MALONE has joined the staff of the Electric Resistance Furnace Company, Ltd., as manager of the new " Efco " foundry division.

ACHESON INDUSTRIES (EUROPE), Ltd., announces that Mr. Edward A. Smith has been appointed a director of Acheson Colloids, Ltd.

MR. IAN ROBINSON has been appointed technical representative in the Sheffield area for Armstrong Whitworth (Metal Industries), Ltd.

THE NORTH BRITISH RUBBER COMPANY, Ltd., has announced the appointment of Mr. C. Thomson, A.M.I.Mech.E., as sales manager, conveyor belting.

DETEL PRODUCTS, Ltd., announces that Sir Oswald A. Scott has been elected chairman, in place of Admiral H. P. Boxer, who did not stand for re-election.

LAMSON ENGINEERING COMPANY, Ltd., announces that Mr. R. L. Herring has retired as managing director and has been succeeded by Mr. D. C. H. McLean.

THE WINSOR ENGINEERING COMPANY, Ltd., announces that Mr. J. M. Rachal, Mr. R. S. Reynolds and Mr. J. Ridge have been co-opted to its board of directors.

THE MINISTRY OF SUPPLY announces that Mr. S. A. Hunwicks has been appointed director of atomic weapons (development), with effect from November 2.

METROPOLITAN-VICKERS ELECTRICAL COMPANY, Ltd., has announced that Mr. J. Dummelow, A.M.I.E.E., has been appointed manager of the publicity department.

SIR W. H. BAILEY AND CO., Ltd., announces that Mr. A. Kirkham has resigned from the board of directors and joined the foundries division of David Brown (Industries), Ltd.

THE BRITISH BROADCASTING CORPORATION announces the appointment of Mr. R. Linton as engineer-in-charge of the new television and v.h.f. sound transmitting station near Peterborough.

THE INSTITUTE OF ROAD TRANSPORT ENGINEERS has announced that Mr. G. Mackenzie Junner, M.I.Mech.E., has been reappointed for the fourteenth year in succession as the president of the Institute.

GEORGE ANGUS AND CO., Ltd., has appointed Mr. H. F. Macintosh as manager of its gear division, in succession to Mr. Wilfred Hirst, who has left to take up an executive appointment with Tweedales-Smalley, Ltd.

MR. A. J. MOSS has been appointed personnel officer at Crompton Parkinson, Ltd.'s British Electric Transformer Works at Hayes, in succession to Mr. D. Rae, who will be taking over other responsibilities at the works.

MR. P. D. CANNING, of The Plessey Company, Ltd., has been appointed chairman of a new sub-committee, 12–7, formed by the International Electro-Technical Commission, to deal with climatic and durability testing of telecommunications equipment.

MATHER AND PLATT, Ltd., announces that Mr. William Loris Mather will become chairman of the board of directors, in succession to his father, Mr. L. E. Mather, who will retire from the chairmanship and also from the board on March 31, 1960.

DOWTY GROUP, Ltd., announces that Mr. A. E. Atkins, production controller of Dowty Equipment, Ltd., has been appointed general works manager. Colonel C. W. King has resigned his position as works director of Rotol, Ltd., and British Messier, Ltd.

W. E. SYKES, Ltd., Staines, Middlesex, announces that Mr. P. A. Cheesman, its area representative for London North of the Thames and Eastern Counties, is shortly to take up a new appointment in the Sykes organisation in the United States. His position will be taken by Mr. G. P. Jones.

COLONEL T. EUSTACE SMITH, chairman and managing director of Smith's Dock Company, Ltd., has been elected president of the Shipbuilding Conference, in succession to Sir James Milne, who has completed his term of office. Mr. Alexander H. White, deputy chairman of Lithgows, Ltd., has been elected vice-president.

THE BRITISH THOMSON-HOUSTON COMPANY, Ltd., announces that Mr. O. W. J. Farmer has been appointed group publicity manager with collective responsibility for publicising the products of the A.E.I. divisions and subsidiary companies managed by The British Thomson-Houston. Mr. Farmer has been succeeded at the A.E.I. Lamp and Lighting Company by Mr. R. E. Hopkin.

THE ENGLISH ELECTRIC COMPANY, Ltd., announces that Mr. E. C. Fox, the company's general manager in India, will become managing director of The English Electric Company of Australia (Pty.), Ltd., at the beginning of January, in succession to Mr. C. W. Goodman, who has passed normal retiring age. Mr. Goodman will continue full-time service as chairman of the Australian company. In India, Mr. N. P. Dingwall, former manager of the company's Calcutta office, will replace Mr. Fox as general manager on November 1.

Business Announcements

COVENTRY CLIMAX ENGINES, Ltd., has opened a new service and spare parts depot at 22–28, Chester Road, Manchester, 15.

SIEMENS EDISON SWAN, Ltd., has opened a new branch office at 247, Western Road, Leicester (telephone, Leicester 58124/5).

KEY ENGINEERING COMPANY, Ltd., Underfloor Duct Division, states that it has opened a London office at Blackfriars House, 19, New Bridge Street, London, E.C.4.

BRUCE PEEBLES AND CO., Ltd., states that Mr. George Henderson, sales director, has retired from full-time executive duties after being with the company for fifty-six years.

A. J. AND J. D. HARRIS, Chartered Civil Engineers, have moved from 75, Victoria Street to 127, Victoria Street, Westminster, London, S.W.1 (telephone, Victoria 6941/2/3).

THE DERITEND STAMPING COMPANY, Ltd., has moved from Liverpool Street, Birmingham, 9, to Bridge House, Station Road, Blackheath, Birmingham (telephone, Blackheath 2261/2).

W. T. HENLEY'S TELEGRAPH WORKS COMPANY, Ltd., 51–53, Hatton Garden, London, E.C.1, announces that it has entered into an arrangement with Voltas, Ltd., who will act as distributors for Henley products in India.

MR. GUY SHOOSMITH, M.I.C.E., M.I.Mech.E., chairman and managing director of Plenty and Son, Ltd., has left on a four-week overseas tour. He is visiting Canada, the United States, Australia, New Zealand, India and Pakistan.

W. H. ALLEN SONS AND CO., Ltd., Queens Engineering Works, Bedford, announces that it has concluded a licensee agreement with the Elsinore Shipbuilding and Engineering Company, Ltd., Denmark, for the construction of three 720kW C.M.R. turbo-alternators.

EFCO, Ltd., Netherby, Queens Road, Weybridge, Surrey, announces that by an agreement with Brown Boveri and Co., Ltd., Switzerland, its subsidiary, The Electric Resistance Furnace Company, Ltd., is to manufacture portable electric mould driers of the Brown Boveri design.

ELGAR MACHINE TOOL COMPANY, Ltd., 172–178, Victoria Road, Acton, London, W.3, states that it has been appointed the exclusive distributor in the United Kingdom for the " Hyop " jig boring machines manufactured by Apparatebau Burkhardt, Pfullingen 6, Reutlingen, Germany.

DEMAG A.G., Compressor Division, Duisberg, has signed an agreement with William H. Capper and Co., Ltd., Mayfair House, 8/9, Hertford Street, London, W.1, under which the British firm has been appointed sole representative in the United Kingdom and Northern Ireland for the sale of all the products of the department.

ALLIS-CHALMERS GREAT BRITAIN, Ltd., Essendine, announces the establishment of Allis-Chalmers Italiana, S.p.A., a majority owned subsidiary of Allis-Chalmers, Milwaukee, Wis., U.S.A., and the acquisition by the Italian company of the facilities of Vender, S.p.A., a manufacturer of crawler tractors and spare parts, located at Cusano, Milan.

DOWTY GROUP, Ltd., Arle Court, Cheltenham, Glos, states that an eight-year contract for the manufacture under licence in Japan of Dowty hydraulic roof-support equipment for coal mines has been granted by Dowty Mining Equipment, Ltd., to Nihon Koki Kabushiki Kaisha (Japanese Mining Equipment Company, Ltd.) of Tokyo. The terms of the agreement give N.K.K.K. selling rights for Dowty mining equipment in Japan and other Far East countries.

Contracts

CABLE AND WIRELESS, Ltd., has placed an order with Cammell Laird and Co. (Shipbuilders and Engineers), Ltd., for a cable repair ship, having a length overall of 367ft by 47·5ft beam and a cable capacity of 21,000 cubic feet or 420 miles of deep sea cable. Diesel-electric propulsion machinery will be installed to give a speed of 15 knots and the ship will be air-conditioned and have an endurance of seven weeks.

HEAD WRIGHTSON STOCKTON FORGE, Ltd., has received an order from the National Coal Board for two sinking headgears to be installed at Kellingley Colliery in the North Eastern Division. Each rising to about 85ft in height above the general pit top level, these riveted structures will be completely clad in 22 gauge galvanised sheet, and they will remain as final guide frames for the operative shafts. The tipping mechanism, bunker chutes, shaft doors, &c., will be pneumatically operated.

MARCONI'S WIRELESS TELEGRAPH COMPANY, Ltd., has received through its Swedish associate, Svenska Radioaktiebolaget, contracts to an approximate value of £1,500,000 for the design and supply of electronic equipment for the Swedish Air Defence System. In this system information on attacking aircraft and missiles, derived by radar, is analysed and displayed on television screens to control room operators. Simultaneously interception problems are worked out by a high-speed computer and appropriate flight instructions are transmitted automatically by radio to defending aircraft and missiles. Tabular and synthetic displays supplemented by televised pictures of ancillary operational data (weather charts, &c.) are provided and large-screen colour television projection displays facilitate assessment of the air situation. Remote synthetic displays may be furnished for civil defence organisations, civil air traffic control centres and similar bodies.

Miscellanea

COLD FORGED BOX SOCKET SPANNERS.—For the manufacture of a new range of box socket spanners a cold forging process has been introduced by Garringtons, Ltd., of Bromsgrove. This is stated to be the first time that cold forging has been employed in the production of box sockets. It is pointed out that these cold forged sockets need no further treatment, the process itself producing in them the same tensile strength as that possessed by ordinary sockets, hot forged from chrome steel and subsequently hardened and tempered. As a result, costs and production time are considerably reduced, enabling the firm to offer forged socket sets at relatively low prices. Both Whitworth and Unified sizes of the new box socket spanners are now available with a new switchover reversible ratchet head.

IMPROVED GUNMETALS.—At an exhibition at Marlands Hall, Southampton, the Mond Nickel Company, Ltd., is showing the properties of an improved gunmetal it has developed in a series of graphs. The new alloy, 85/6·5/3/3·5/2 Cu-Sn-Zn-Pb-Ni, is stated to have stable and better mechanical properties at both atmospheric and elevated temperatures than 85/5/5/5 gunmetal and it still retains the same adaptability to the production of pressure-tight castings. When properly made, castings in this alloy have a 0·1 per cent proof stress of around 8 tons per square inch with a maximum stress of 16–17 tons per square inch in sections up to 3in thick. The mechanical properties can now be related to those obtained from separately-cast test bars. The improved gunmetal is one of a range of uses of nickel and nickel-containing materials to be featured at the Southampton exhibition which will be open from October 27 to 30.

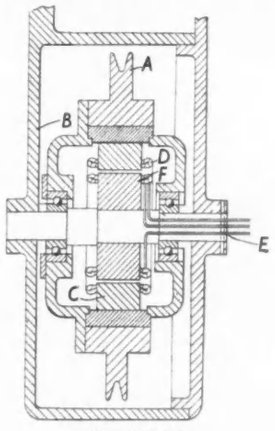
British Patent Specifications

When an invention is communicated from abroad the name and address of the communicator are printed in italics. When an abridgment is not illustrated the specification is without drawings, unless otherwise stated. The date first given is the date of application; the second date, at the end of the abridgment, is the date of publication of the complete specification. Copies of specifications may be obtained at the Patent Office Sales Branch, 15, Southampton Buildings, Chancery Lane, W.C.2, 3s. 6d. each.

ELECTRICAL ENGINEERING

820,460. December 6, 1957.—Remote Angular Position Indicating Devices, The British Thomson-Houston Company, Ltd., Crown House, Aldwych, London, W.C.2. (*Inventors: Dennis Surridge Morfey and Leslie Carter Ludbrook.*)

This invention relates to remote angular position indicating, using a transmitting selsyn device which avoids the need for slip rings by using on the rotating element of the transmitter a single-phase short-circuited winding. This is arranged to induce in a quadrature winding on the receiver a voltage dependent upon the degree of coupling provided by the stator windings of the transmitter and receiver, the voltage thus induced in the quadrature winding being employed to energise one phase of a two-phase motor coupled to the rotor of the receiver, so that the motor drives the receiver into correspondence with the transmitter. The rotating element of the transmitter illustrated can be coupled to a movable band



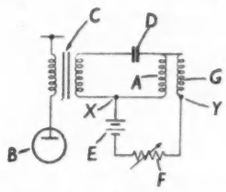
No. 820,460

or rope so as to transmit an indication of movement Referring to the drawing, a pulley *A* rotates on bearings within the housing *B*, the housing having an opening or openings for the passage of a cord, rope or belt, the movement of which is to be indicated. Within the pulley is secured the rotating element *C* of the transmitter selsyn, the rotating element being furnished with a single-phase short-circuited winding *D*. The bearings are mounted on stationary shaft *E* extending between bosses on the housing. On the shaft *E* is fixedly mounted the stator *F* of the transmitter. The stator is provided with a winding in which a polyphase distribution of voltages is induced from the short-circuited winding on the rotor. The stator winding may consist of a star-connected three-phase winding, the end terminals of which are connected to the similar terminals of a polyphase winding on the receiver; alternatively, the stator may be provided with two single-phase windings suitably phase-displaced to provide an effective star point which, with the outer terminals of the windings, provides the three-phase terminals for connection to the three-phase winding on the receiver. The connections to the windings on the stator are brought out through the shaft *E* in any suitable manner.—*September* 23, 1959.

ELECTRONICS

820,756. February 13, 1958.—Magnetic Deflecting Circuits for a Cathode-Ray Tube, Electric and Musical Industries, Ltd., Blyth Road, Hayes, Middlesex. (*Inventor: Eric William Bull.*)

In a magnetic deflection circuit for a cathode-ray tube it is often found desirable to apply a unidirectional "shift" current to the scanning coil for the purpose of centring the beam. The object of the present invention is to provide an improved circuit in which the result can be achieved without substantial loss of scanning power. Referring to the drawing, reference *A* denotes a scanning coil for a cathode-ray tube, the coil being, for example, the line scanning coil of a television receiver. The coil is fed with a current variation of sawtooth waveform by a driving valve *B* by way of a transformer *C* and a blocking condenser *D*. The valve *B* is only partly

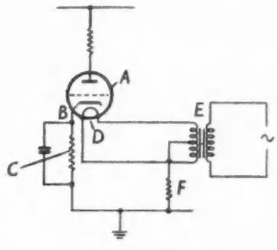


No. 820,756

illustrated, since the connections to it may be conventional. A source of shift current represented by a battery *E* has one terminal connected to the lower end (in the drawing) of the coil *A* and has the other terminal connected by way of a variable resistor *F* and an auxiliary coil *G* to the upper end of the coil *A*. The coil *G* is magnetically coupled, at least to some degree, with the coil *A*, and the auxiliary coil is wound with such turns that as a result of the said coupling the voltage induced by the scanning current is equal to that of the scanning coil. The auxiliary coil *G* is, moreover, wound in opposite sense to the coil *A* so that the resultant voltage across the scanning coil and the auxiliary coil in series is substantially zero. Therefore, as the scanning current produces substantially no voltage between the points *X* and *Y* indicated in the drawing, the shift source and the auxiliary coil do not by-pass a substantial proportion of the scanning current, and a shift current may be fed into the scanning coil *A* without significant wastage of power. Variation of resistor *F* allows the shift current to be adjusted, whilst the blocking condenser *D* prevents current from the source *E* from flowing in the secondary winding of the transformer *C*, which would result in reduction of the shift sensitivity.—*September* 23, 1959.

820,482. November 16, 1954.—Audio Electronic Amplifiers, The British Thomson-Houston Company, Ltd., Crown House, Aldwych, London, W.C.2. (*Inventor: James Moir.*)

In the first stage of an audio-frequency amplifier where grid bias is obtained by means of a resistor in the cathode circuit, the resistor being shunted by a capacitor, a short circuit between cathode and heater could result in an a.c. voltage at mains frequency being applied to the cathode. It follows that the cathode potential will therefore vary relative to the grid so that the signal will be applied to the input end of the amplifier, seriously overloading the subsequent valves and the loudspeakers. According to the present invention, a protective ohmic resistance having an impedance at least ten times that of the cathode circuit is included between the heater, transformer and the cathode circuit so that in the case of a breakdown between cathode and heater circuits the voltage developed across the cathode impedance due to the cathode heater supply is negligible. In the arrangement shown in the drawing



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A represents a thermionic valve in the first stage of an electronic amplifier. The cathode *B* is connected through a cathode resistor *C* shunted by a condenser to the negative h.t. supply line. The heater *D* is fed from the secondary winding of a supply transformer *E*, of which the centre tap is connected through a protective resistor *F* to the negative supply line and hence to the negative end of resistor *C*. Without protective resistance *F*, should a fault occur between the cathode and the heater, a closed circuit will be established through the capacitor and cathode circuit which includes half of the transformer secondary winding and if, taking a typical example, the voltage across the half of the secondary winding is 3·15V, this will be injected into the above-mentioned closed circuit and will be applied as a modulating voltage to the cathode. By connecting, in the circuit between the tapping point of the transformer and the negative end of resistor *C*, the protective resistance *F* with an impedance which is high relative to the cathode impedance of *C* and its shunt capacitor, the voltage drop due to the current flow will occur substantially entirely across the protective resistance and the voltage developed across the cathode impedance which will, of course, be applied to the input end of the amplifier, will be reduced to negligible amplitude.—*September* 23, 1959.

TELECOMMUNICATIONS

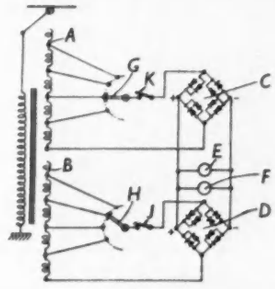
820,483. November 25, 1955.—Variable Reactances for Microwaves, Electric and Musical Industries, Ltd., Blyth Road, Hayes, Middlesex. (*Inventor: Frederick Henry Gale.*)

According to this invention, a variable reactance for microwaves is in the form of a vane twisted about an axis and mounted in a rectangular wave guide with its axis lying substantially along the wave guide so that the vane can be rotated. The section of the vane most liable to reflect electromagnetic waves is that parallel to the electric field in the guide, and as the vane is rotated, this section moves along the wave-guide by virtue of the twist of the vane. An effect is produced, therefore, which is similar to that obtained by varying the length of a short-circuited waveguide. In one form of the invention the vane is mounted in the guide so as to form therewith a resonant cavity and means are provided for adjusting the angular setting of the vane to vary the resonant frequency. The adjusting knob and pointer may be calibrated directly in reactance or frequency. In another form of the invention, the vane is mounted for continuous rotation about its axis so that when electromagnetic waves are incident on the vane, waves are reflected from it differing from the incident waves in frequency in dependence upon the rate of rotation of the vane, thereby simulating the doppler effect which arises when waves are reflected from a moving body. This form of the invention may therefore be called a doppler simulator, and is useful for testing purposes. The vane may be in the form of a helically twisted strip but other structures which are electrically equivalent may also be used, such as a series of rods or strips angularly disposed about the axis of twist and spaced in succession along the axis.—*September* 23, 1959.

ELECTRIC TRACTION

820,596. June 19, 1957.—Control System for Railway Vehicles, Forges et Ateliers de Constructions Electriques de Jeumont, 5, Place de Rio-de-Janeiro, Paris, France.

When electric locomotives or motor rail vehicles have their driving motors supplied with rectified current through tapped transformers, the tapping switches necessarily comprise resistances or reactances for limiting the short-circuit currents in the transformer winding sections. In accordance with this invention, however, the tappings of the transformer are divided into groups controlled by separate groups of tapping switches, each associated with a power switch and with a distinct set of single-anode rectifier elements in bridge connection, and short-circuit currents are eliminated by the rectifier elements. Referring to the diagram, the two secondary windings *A* and *B* feed two distinct rectifier sets *C* and *D* which operate in parallel to supply direct current to driving motors *E* and *F*. It will be assumed at first that the selectors *G* and *H* are on corresponding tappings so that each rectifier set supplies half the load. When, however, the power switch *J* is opened, the set *D* is temporarily put out of action, and for a short time the set *C* takes over the whole load. During this transition period, the selector *H* moves idly on to the next tapping, as shown, and when the power switch closes again, the set *D* will assume practically the entire load under an increased voltage. This transfer of the power is due to the fact that if two rectifiers are connected in parallel, the one which gives the lower voltage does not supply any current. It should also be noted that despite the inequality of



No. 820,596

the two voltages given by the windings *A* and *B*, no circulating current can pass between them. In fact, in the position shown, the rectifier set *C* opposes the short-circuit current, the result being the same as if the winding *A* were disconnected. Immediately after, the power switch *K* opens and the selector *G* moves to the next tapping. Switch *K* then closes again and re-establishes the equality of the two feed voltages; the load is again distributed equally to the two rectifier sets. In order to reduce the voltage at the terminals of the driving motors, the operations of the selectors and power switches are effected in the inverse order. Means may be adopted for connecting the rectifier elements in series on the higher-voltage tappings, and an alternative scheme is illustrated in the specification, by which the number of tappings required for a given range of voltages is reduced.—*September* 23, 1959.

Launches and Trial Trips

KITTIWAKE, lightship; built by Philip and Son, Ltd., for the Commissioners of Irish Lights; length overall 136ft 5in, beam 25ft, depth moulded 15ft; 1¼in Tayco mooring cable, 4-ton mushroom anchor two 35 cwt emergency anchors, lantern 40ft above sea level, range 10 miles; two 9kW and two 4½kW diesel-driven generators, two diesel-driven air compressors. Trial, July.

SANTONA, open shelter deck cargo ship; built by Hall, Russell and Co., Ltd., for The Donaldson Line, Ltd.; length between perpendiculars 270ft, breadth moulded 44ft 6in, depth moulded to shelter deck 26ft, 2500 tons deadweight on 17ft 10in draught; three holds, two 7-ton and six 5-ton derricks; two 125kW and one 60kW diesel-driven generators; British Polar five-cylinder, single-acting, two-stroke trunk piston diesel engine, 2000 service brake horsepower. Trial, July 31.

HOLMSIDE, bulk carrier; built by Hall, Russell and Co., Ltd., for The Burnett Steamship Company, Ltd.; length between perpendiculars 370ft, breadth moulded 53ft, depth moulded 28ft, deadweight 6500 tons on 22ft 3in draught; four holds, eight 5-ton derricks; three 125kW diesel-driven generators; Clark-Sulzer six-cylinder, single-acting, two-stroke diesel engine, 3000 b.h.p. at 150 r.p.m., arranged to burn heavy oil. Trial, August 26.

BANKURA, cargo ship; built at the Govan yard of Harland and Wolff, Ltd., for the British India Steam Navigation Company, Ltd.; length between perpendiculars 395ft, breadth moulded 59ft, depth moulded to upper deck 32ft 6in, deadweight 7350 tons, service speed 16 knots; four cargo holds, five deck cranes, and four 10-ton derricks, push-button MacGregor hatch covers; four 350kW, 440V diesel-driven alternators; Harland and Wolff two-stroke, single-acting, opposed piston diesel engine, six cylinders, 620mm diameter by 1870mm combined stroke, 118 r.p.m. Trial, August 27.

CITY OF MELBOURNE, general and refrigerated cargo liner; built by Alexander Stephen and Sons, Ltd., for Ellerman Lines, Ltd.; length between perpendiculars 510ft, breadth moulded 71ft, depth 33ft 6in, draught 28ft 9¼in, deadweight 12,300 tons, gross tonnage 9920; five main cargo holds, one 20-ton, eight 10-ton, four 7-ton, and six 5-ton derricks, electric winches, MacGregor steel hatch covers; four 300kW generators; Stephen-Sulzer turbo-charged diesel engine, twelve cylinders, 14,000 b.h.p. at 114·5 r.p.m., 18,220 b.h.p. at 126 r.p.m., arranged to burn heavy fuel. Trial, August 28.

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office not later than a fortnight before the meeting. In all cases the TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

ANTIQUARIAN HOROLOGICAL SOCIETY

To-day, Oct. 23.—Science Museum, South Kensington, London, S.W.7, "The Contributions of Arnold and Earnshaw to the Development of the Marine Chronometer," D. W. Evans, 7 p.m.

ASSOCIATION OF SUPERVISING ELECTRICAL ENGINEERS

To-day, Oct. 23.—LEEDS BRANCH AND RAMSEY REGIONAL LECTURE: Chemistry Lecture Theatre "A," The University, Leeds, "The Prospects of Power from Controlled Thermo-nuclear Energy," A. E. Robson, 7.30 p.m.

Sat., Oct. 24.—SOUTH EAST LONDON BRANCH: Visit to Dartford Paper Mills, 10 a.m.

Tues., Oct. 27.—EAST KENT BRANCH: County Hotel, Canterbury, "Protective Equipment for Industrial Plant," W. L. Stern, 8 p.m.

Thurs., Oct. 29.—BRIGHTON, HOVE AND DISTRICT BRANCH: New Imperial Hotel, First Avenue, Hove, "Application of Temperature Control," 7.30 p.m.

Fri., Oct. 30.—COVENTRY AND DISTRICT BRANCH: Visit to Lockheeds, Ltd., Leamington Spa, 7.30 p.m. ★ STOKE AND CREWE BRANCH: Grand Hotel, Hanley, "Hospital Electrical Installations," G. Middlemas, 7.30 p.m.

BRITISH INSTITUTE OF MANAGEMENT

Fri., Oct. 30.—FIFTH ELBOURNE MEMORIAL LECTURE: Assembly Hall, Royal Commonwealth Society, Northumberland Avenue, London, W.C.2, "The Management Burden," H. Wilmot 8 p.m.

BRITISH INSTITUTION OF RADIO ENGINEERS

To-day, Oct. 23.—SCOTTISH SECTION: Department of Natural Philosophy, The University, Drummond Street, Edinburgh, "True Motion Radar," J. H. Beattie, 7 p.m.

Tues., Oct. 27.—SOUTH MIDLANDS SECTION: Winter Gardens, Malvern, "Superconducting Computer Stores," Mrs. L. Roberts, 7 p.m.

Wed., Oct. 28.—RADAR AND NAVIGATIONAL AIDS GROUP: London School of Hygiene and Tropical Medicine, Keppel Street, Gower Street, London, W.C.1, "Radio—Its Impact on Shipping," Captain J. D. F. Elvish; "A Historical Survey of Radar and Radio Aids to Aircraft Navigation," Air Marshal Sir Raymund G. Hart, 6.30 p.m. ★ SOUTH WALES SECTION: College of Advanced Technology, Cardiff, "Stereophonic Sound and Electrostatic Loudspeakers," 6.30 p.m.

Mon., Nov. 2.—MERSEYSIDE SECTION: University Club, 2, Mount Pleasant, Liverpool, "Electronics in the Auto-Pilot of the 'Firestreak' Missile," A. Bedford, 7 p.m.

CEMENT AND CONCRETE ASSOCIATION

Wed., Oct. 28.—Constantine Technical College, Borough Road, Middlesbrough, One-day Symposium arranged in conjunction with the Middlesbrough Education Committee, "Electronic Digital Computers in Structural Design," 9.30 a.m.

INSTITUTE OF BRITISH FOUNDRYMEN

Tues., Oct. 27.—SLOUGH SECTION: Lecture Theatre, High Duty Alloys, Ltd., Slough, "Casting Defects," J. L. Francis, 7.30 p.m.

INSTITUTE OF MARINE ENGINEERS

Wed., Oct. 28.—SCOTTISH SECTION: Small Hall, The Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, C.2, "The Engineer Surveyor," A. T. Willens, 7.30 p.m. ★ MERSEYSIDE AND NORTH WESTERN SECTION: Liverpool Engineering Society, The Temple, Dale Street, Liverpool, Joint Meeting with the Liverpool Engineering Society, "Present and Future Developments in Heavy Forging," R. C. Benson, 6 p.m.

Thurs., Oct. 29.—INFORMAL MEETING: Memorial Building, 76, Mark Lane, London, E.C.3, Discussion on "Steam Versus Diesel Propulsion for Large Ships," introduced by L. Greenacre and C. B. Robinson, 5.30 p.m.

Mon., Nov. 2.—STUDENT MEETING: Memorial Building, 76, Mark Lane, London, E.C.3, Discussion on "The Day to Day Management of a Ship and its Machinery," 6.30 p.m. ★ MERSEYSIDE AND NORTH WESTERN SECTION: Liverpool Engineering Society, The Temple, Dale Street, Liverpool, "Nuclear Propulsion of Ships," R. P. Kinsey, 6 p.m.

INSTITUTE OF ROAD TRANSPORT ENGINEERS

Mon., Nov. 2.—EAST REGIONAL CENTRE: Council Chamber, Houldsworth Hall, 90, Deansgate, Manchester, "Driving Technique," 7.30 p.m. ★ SCOTTISH CENTRE: Institution of Engineers and Shipbuilders, Elmbank Crescent, Glasgow, "Chassis and Engine Manufacture," R. P. Chilton, 7.30 p.m.

INSTITUTE OF SHEET METAL ENGINEERING

Wed., Oct. 28.—WOLVERHAMPTON SECTION: Wolverhampton and Staffordshire College of Technology, Wulfruna Street, Wolverhampton, "Sheet and Strip Steel," A. S. Huxley, 6.45 p.m.

INSTITUTE OF WELDING

Wed., Oct. 28.—MEDWAY SECTION: Sun Hotel, Chatham, "Design for Draughtsmen," H. B. Merriman, 7.30 p.m.

INSTITUTION OF CIVIL ENGINEERS

Tues., Oct. 27.—Great George Street, Westminster, London, S.W.1, "Some Structural Aspects of the Design of Concrete Pipelines," N. W. B. Clarke and O. C. Young, 5.30 p.m.

INSTITUTION OF ELECTRICAL ENGINEERS

Mon., Oct. 26.—EAST ANGLIAN SUB-CENTRE: Cavendish Laboratory, Cambridge, Discussion on "The Teaching of Electricity to Engineers and Physicists," 7 p.m. ★ MERSEY AND NORTH WALES CENTRE: Town Hall, Chester, "H.V. D.C. Transmission with Special Reference to Cross Channel Cable," F. J. Lane, 6.30 p.m. ★ NORTH-EASTERN CENTRE: Neville Hall, Westgate Road, Newcastle upon Tyne, "The Provision of Adequate Electrical Installations in Buildings: (*a*) 'Multi-Storey Flats and Maisonettes,' C. A. Belcher; (*b*) 'Commercial Buildings,'" E. E. Jacobi, 6.15 p.m. ★ SHEFFIELD SUB-CENTRE: Angel Hotel, Brigg, Chairman's Address, "Permanent Magnets and the Electrical Engineer," F. G. Tyack, 6.45 p.m. ★ SOUTH MIDLAND ELECTRONICS AND COMMUNICATIONS GROUP: James Watt Institute, Birmingham, "Reliability of Electronic Equipment," A. G. Field, 6 p.m. ★ WESTERN UTILIZATION GROUP: S.W.E.B. Demonstration Theatre, Colston Avenue, Bristol, Section Chairman's Address, T. E. Houghton, 6 p.m.

Tues., Oct. 27.—MEASUREMENT AND CONTROL SECTION: Savoy Place, London, W.C.2, Discussion on "Future Trends in Memory Stores for High-Speed Digital Computers," opened by W. Renwick, 5.30 p.m. ★ NORTH-WESTERN MEASUREMENT AND CONTROL GROUP: Engineers' Club, Albert Square, Manchester, "The Influence of Consumers' Load/Consumption Characteristics on Metering Practice," L. B. S. Golds, 6.15 p.m. ★ SOUTH-WEST SCOTLAND SUB-CENTRE: Royal College of Science and Technology, George Street, Glasgow, C.1, "A New Method for Observing the Phenomena of Commutation," H. J. H. Sketch, P. A. Shaw and R. J. K. Splatt, 6 p.m.

Wed., Oct. 28.—ELECTRONICS AND COMMUNICATIONS SECTION: Savoy Place, London, W.C.2, Chairman's Address, "Development of Eurovision," M. J. L. Pulling, 5.30 p.m. ★ NORTH LANCASHIRE SUB-CENTRE: North Western Electricity Board Demonstration Theatre, Duke Street, Barrow, "Discrimination between H.R.C. Fuses," E. Jacks, 7.15 p.m. ★ RUGBY SUB-CENTRE: College of Technology and Arts, Rugby, Joint Meeting with the Rugby Engineering Society, "The Deltic Locomotive," C. M. Cock, 6.30 p.m.

Thurs., Oct. 29.—NORTH SCOTLAND SUB-CENTRE: Electrical Engineering Department, Queen's College, Dundee, Chairman's Address, A. J. O. Cruickshank, 7 p.m.

Fri., Oct. 30.—NORTH SCOTLAND SUB-CENTRE: Robert Gordon's Technical College, Aberdeen, Chairman's Address, A. J. O. Cruickshank, 7.30 p.m. ★ NORTH STAFFORDSHIRE SUB-CENTRE: Technical College, Stoke-on-Trent, "The Design and Performance of the Gas-Filled Cable System," E. P. G. Thornton and D. H. Booth, 7 p.m.

INSTITUTION OF HIGHWAY ENGINEERS

To-day, Oct. 23.—NORTH EAST BRANCH: University Science Laboratories, South Road, Durham, "Recent Developments in Coated Macadam and Cold Asphalt," A. E. T. Lawrence, 7 p.m.

INSTITUTION OF MECHANICAL ENGINEERS

Sat., Oct. 24.—EASTERN GRADUATES' SECTION: Visit to Woods of Colchester, 9.30 a.m.

Tues., Oct. 27.—AUTOMOBILE DIVISION: 1, Birdcage Walk, Westminster, London, S.W.1, "Engineering Challenges to American Automotive and Petroleum Research," L. Raymond, 6 p.m.

Wed., Oct. 28.—ORDINARY MEETING IN CONJUNCTION WITH THE APPLIED MECHANICS GROUP: 1, Birdcage Walk, Westminster, London, S.W.1, "Strength of Thick Cylinders Subjected to Repeated Internal Pressure," J. L. M. Morrison, B. Crossland and J. S. C. Parry, 6 p.m. ★ YORKSHIRE BRANCH: The University, St. George's Square, Sheffield, "Industrial Applications of Oil Hydraulics," F. B. Levetus, 6.30 p.m. ★ EASTERN GRADUATES' SECTION: College of Technology, Luton, "Performance Testing of Tyrex Tyre Cords," 7.30 p.m.

Thurs., Oct. 29.—WESTERN A.D. CENTRE: Royal Hotel, Bristol, Repetition of A.D. Chairman's Address, 6.45 p.m. ★ EAST MIDLANDS GRADUATES' SECTION: College of Technology and Commerce, Leicester, Film Show, 7.15 p.m. ★ SOUTHERN GRADUATES' SECTION: South Dorset Technical College, Weymouth, "Design of Pumps and Compressors," F. Pollak, 7.30 p.m.

Fri., Oct. 30.—COVENTRY GRADUATES' SECTION: Visit to the works of Alvis, Ltd., Holyhead Road, Coventry, 7.30–9 p.m. ★ EAST MIDLANDS GRADUATES' SECTION: Visit to the Metal Box Company, Ltd., Addicroft Works, Sutton-in-Coldfield, Notts, 7 p.m.

Sat., Oct. 31.—WESTERN BRANCH: Visit to the Severn Pumping Station of British Railways, 2 p.m.

Mon., Nov. 2.—NORTH EASTERN BRANCH: Institute of Mining and Mechanical Engineers, Neville Hall, Newcastle, 1, Joint Meeting with the local branch of the Institution of Production Engineers, "Production, Fabrication, Properties and Uses of Some of the Newer Metals," N. P. Inglis, 6 p.m.

INSTITUTION OF PLANT ENGINEERS

To-day, Oct. 23.—BIRMINGHAM BRANCH: Imperial Hotel, Temple Street, Birmingham, "Industrial Floorings," W. J. Warlow, 7.30 p.m.

Mon., Oct. 26.—WEST AND EAST YORKSHIRE BRANCH: Houldsworth School of Applied Science, The University, Leeds, "A.C. Motors and their Application," F. T. Bartho, 7.30 p.m.

Tues., Oct. 27.—SOUTH WALES BRANCH: South Wales Institute of Engineers, Park Place, Cardiff, "Properties of Molybdenum Disulphide and Its Use as Plant Engineering Material," H. P. Jost, 7.30 p.m.

Thurs., Oct. 29.—SHEFFIELD AND DISTRICT BRANCH: Grand Hotel, Sheffield, "Lifting Tackle," G. E. Simm, 7.30 p.m.

INSTITUTION OF PRODUCTION ENGINEERS

Mon., Oct. 26.—NORTH WESTERN REGION: Reynolds Hall, Manchester College of Science and Technology, Sackville Street, Manchester, "Applications of Hydro-Pneumatic Circuits," J. M. Kenworth, 7.15 p.m.

Wed., Oct. 28.—MIDLANDS REGION: Technical College, Shrewsbury, "Production in Western Germany," A. C. Turner, 7.30 p.m.

Thurs., Oct. 29.—NORTH MIDLANDS REGION: Ruston Club, Lincoln, "Work Measurement and its Uses for Management," W. Hewett, 7.30 p.m.

Mon., Nov. 2.—NORTHERN REGION: Institute of Mining and Mechanical Engineers, Neville Hall, Newcastle, 1, "The Production, Fabrication, Properties and Uses of Some of the Newer Metals," N. P. Inglis, 6 p.m.

INSTITUTION OF STRUCTURAL ENGINEERS

To-day, Oct. 23.—MIDLAND COUNTIES BRANCH: James Watt Memorial Institute, Birmingham, Chairman's Address, A. T. Clarke, 6.30 p.m.

Thurs., Oct. 29.—WALES AND MONMOUTHSHIRE BRANCH: South Wales Institute of Engineers, Cardiff, Chairman's Address, "The Structural Aspect of Pipe Problems," C. D. C. Braine, 6.30 p.m.

JUNIOR INSTITUTION OF ENGINEERS

To-day, Oct. 23.—Pepys House, 14, Rochester Row, Westminster, London, S.W.1, "Some Recollections of Past Secretary H. G. Riddle as a Model and Experimental Engineer," H. J. N. Riddle, 7 p.m.

Fri., Oct. 30.—Pepys House, 14, Rochester Row, Westminster, London, S.W.1, "Planning a Computer Job," M. G. Ferrand, 7 p.m.

LIVERPOOL JOINT CHEMISTRY COMMITTEE

Thurs., Oct. 29.—Lecture Theatre, The University, Vine Street, Liverpool, "The Growth of Fluorocarbon Chemistry," R. N. Haszeldine, 5 p.m.

Fri., Oct. 30.—Lecture Theatre, The University, Vine Street, Liverpool, "Bulk Handling and Storage of Heavy Chemicals," W. A. S. White, 7.30 p.m.

MANCHESTER ASSOCIATION OF ENGINEERS

To-day, Oct. 23.—Engineers' Club, Albert Square, Manchester, 2, "Design and Construction of the Latest Self-Righting Lifeboat," R. A. Oakley, 6.45 p.m.

NORTH EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS

Fri., Oct. 30.—Lecture Theatre, Literary and Philosophical Society, Newcastle upon Tyne, Opening General Meeting; Film "The Dounreay Fast Reactors," 6.15 p.m.

Mon., Nov. 2.—ANDREW LAING LECTURE: Lecture Theatre, Literary and Philosophical Society, Newcastle upon Tyne, "Machinery for Large Tankers," G. B. Halley, 6.15 p.m.

PLASTICS INSTITUTE

Mon., Nov. 2.—MIDLANDS SECTION: James Watt Memorial Institute, Great Charles Street, Birmingham, 3, "High-Speed Injection Moulding and Latest Development in Injection Moulding Technique," E. Gaspar, 6.30 p.m.

REINFORCED CONCRETE ASSOCIATION

Thurs., Oct. 29.—WEST OF ENGLAND BRANCH: New School of Engineering, The University, Bristol, "The Architectural Expression of Structural Concrete," W. A. Gibbon, 6 p.m.

ROYAL AERONAUTICAL SOCIETY

Tues., Oct. 27.—MAIN LECTURE: Church House, Westminster, London, S.W.1, "Aircraft Fatigue—A Survey of Current Thought," R. J. Atkinson, 7 p.m.

Wed., Oct. 28.—GRADUATES' AND STUDENTS' SECTION: Library, 4, Hamilton Place, London, W.1, "The Setting of Aircraft Specifications," R. H. Whitby, 7.30 p.m.

Thurs., Oct. 29.—SPECIAL GENERAL MEETING: 4, Hamilton Place, London, W.1, "The Society and the Helicopter Association," 6.30 p.m.

Fri., Oct. 30.—MAN-POWERED AIRCRAFT GROUP: The Library, 4, Hamilton Place, London, W.1, Inaugural Meeting, 7 p.m.

SOCIETY OF ENGINEERS

Mon. Nov. 2.—Geological Society, Burlington House, Piccadilly, London, W.1, "The Dissemination of Technical Information with Particular Reference to the Aircraft Industry," K. A. Steel, 5 p.m.

SOCIETY OF INSTRUMENT TECHNOLOGY

Tues., Oct. 27.—Manson House, 26, Portland Place, London, W.1, "Modern Developments in Optical Instruments," J. H. Bach and G. E. Fishter, 6.30 p.m.

WEST OF SCOTLAND IRON AND STEEL INSTITUTE

To-day, Oct. 23.—Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, Presidential Address, J. W. Todd, 6.45 p.m.

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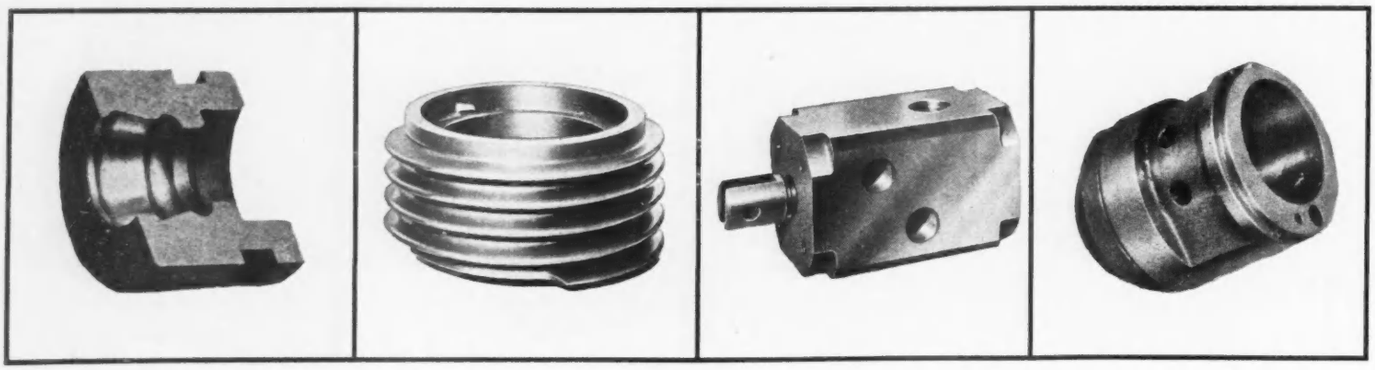

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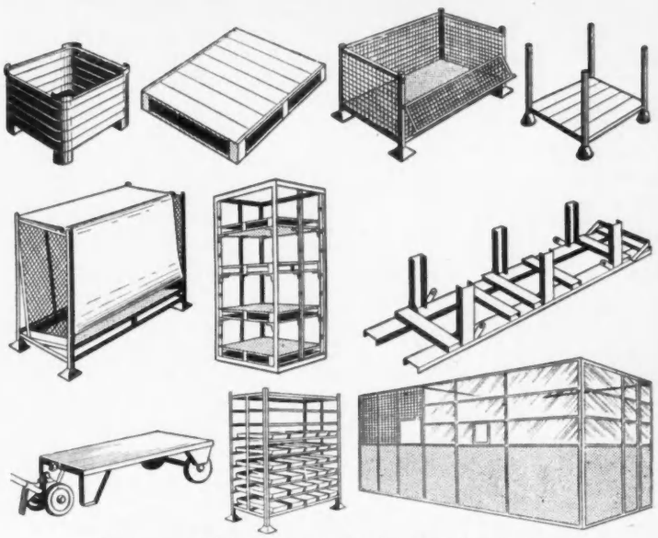

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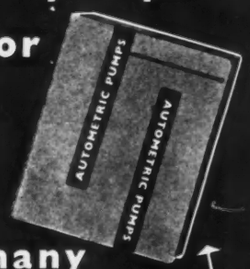

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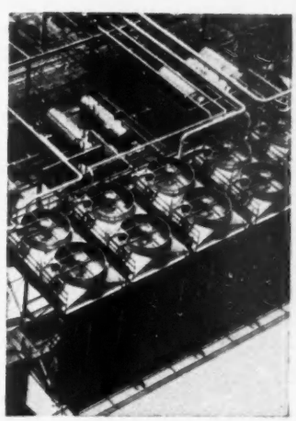

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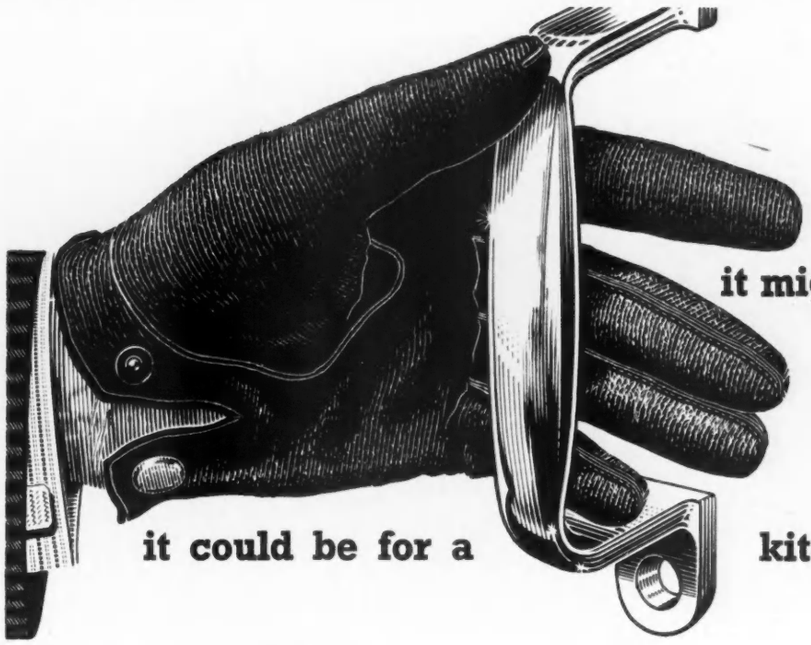

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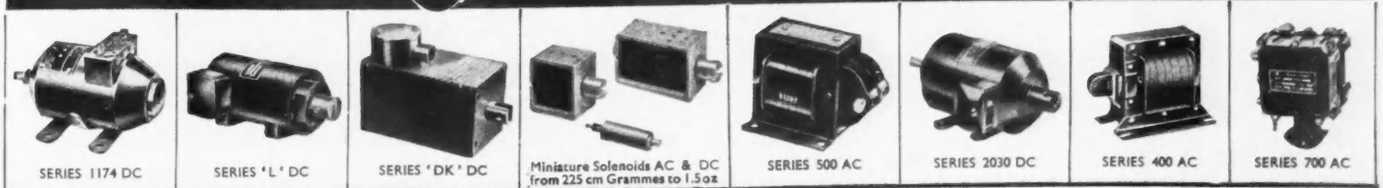

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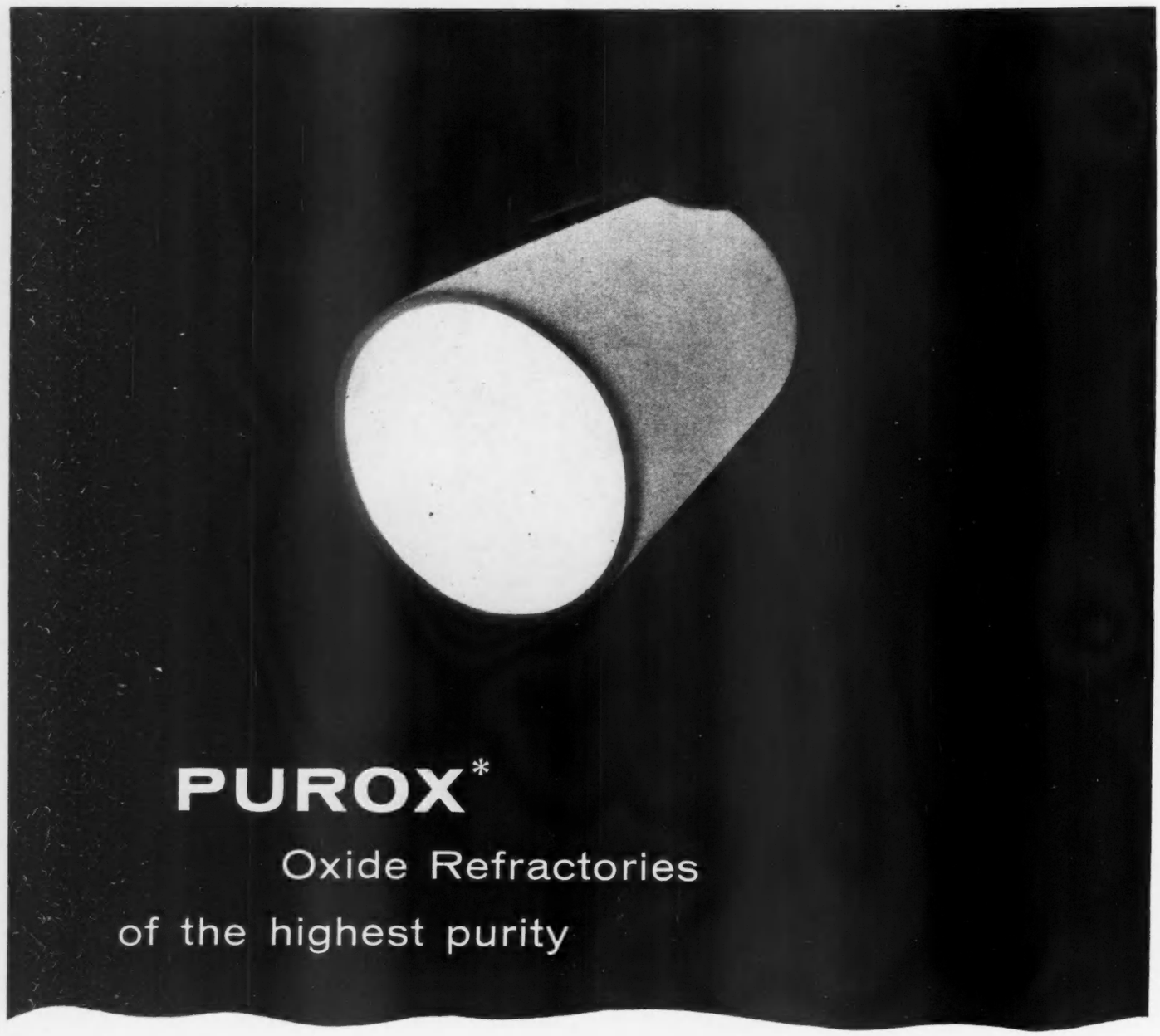

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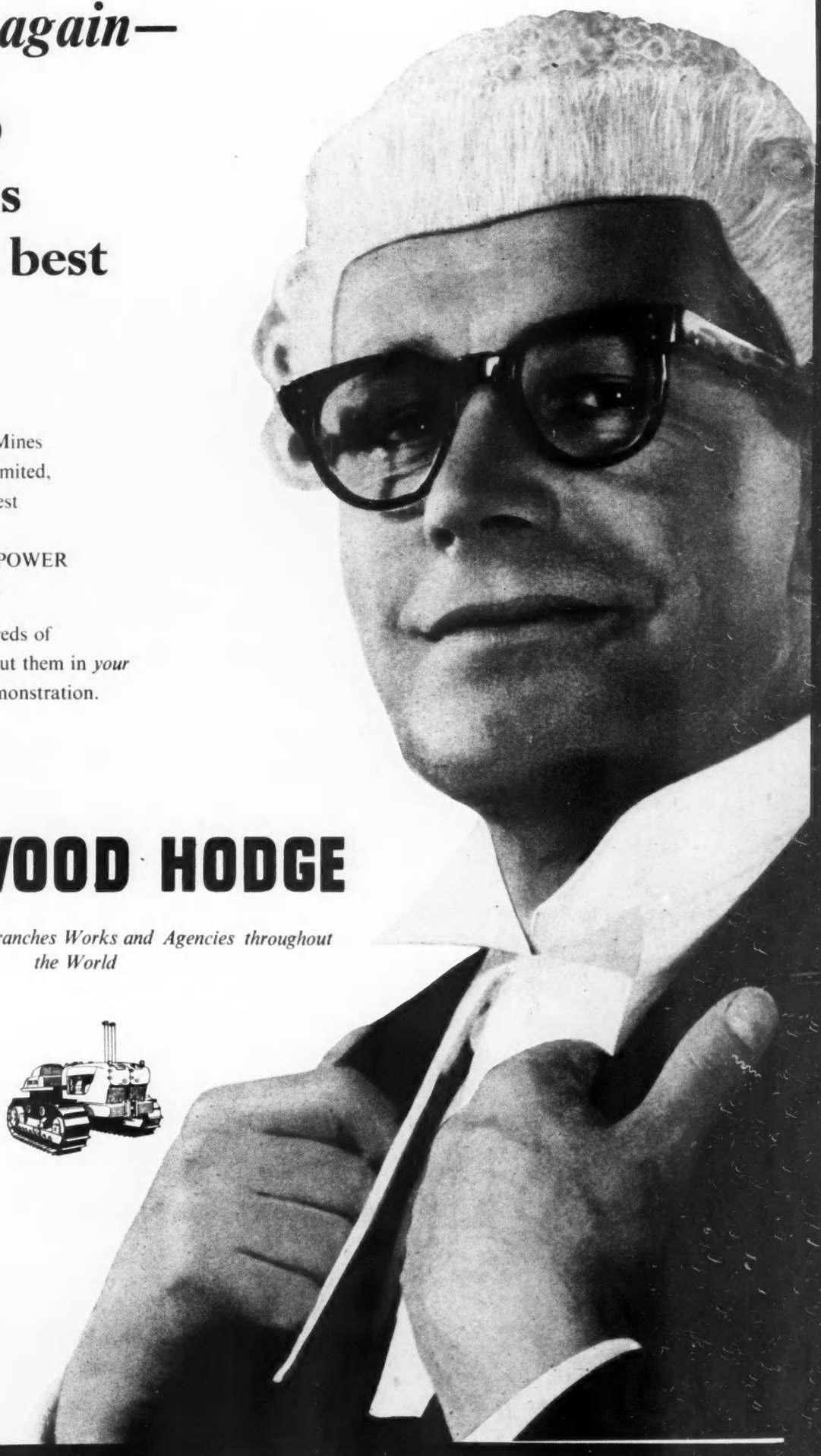

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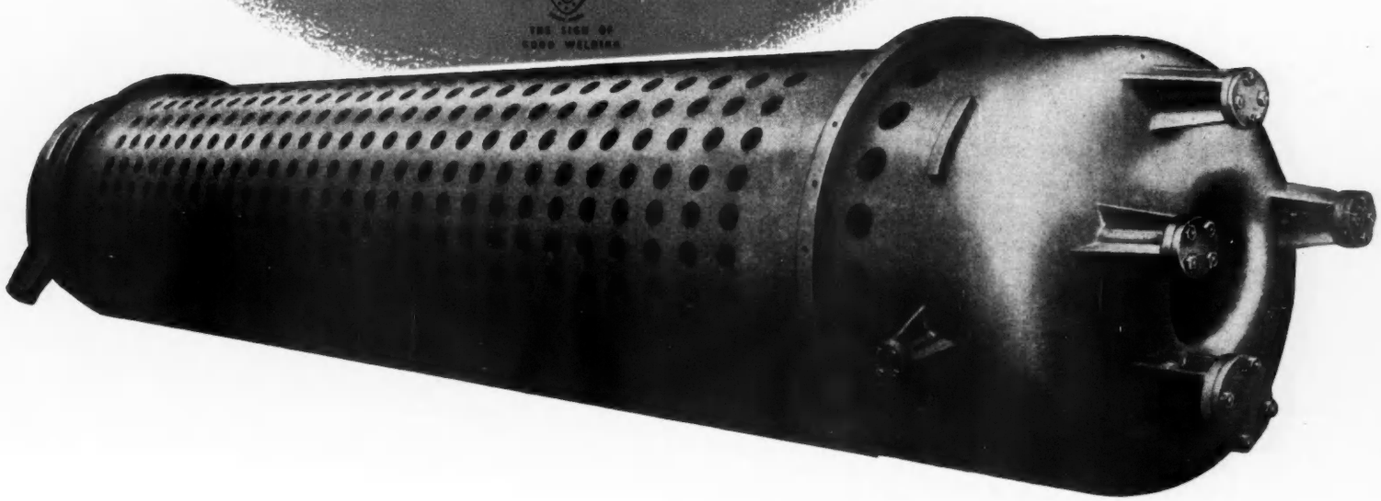

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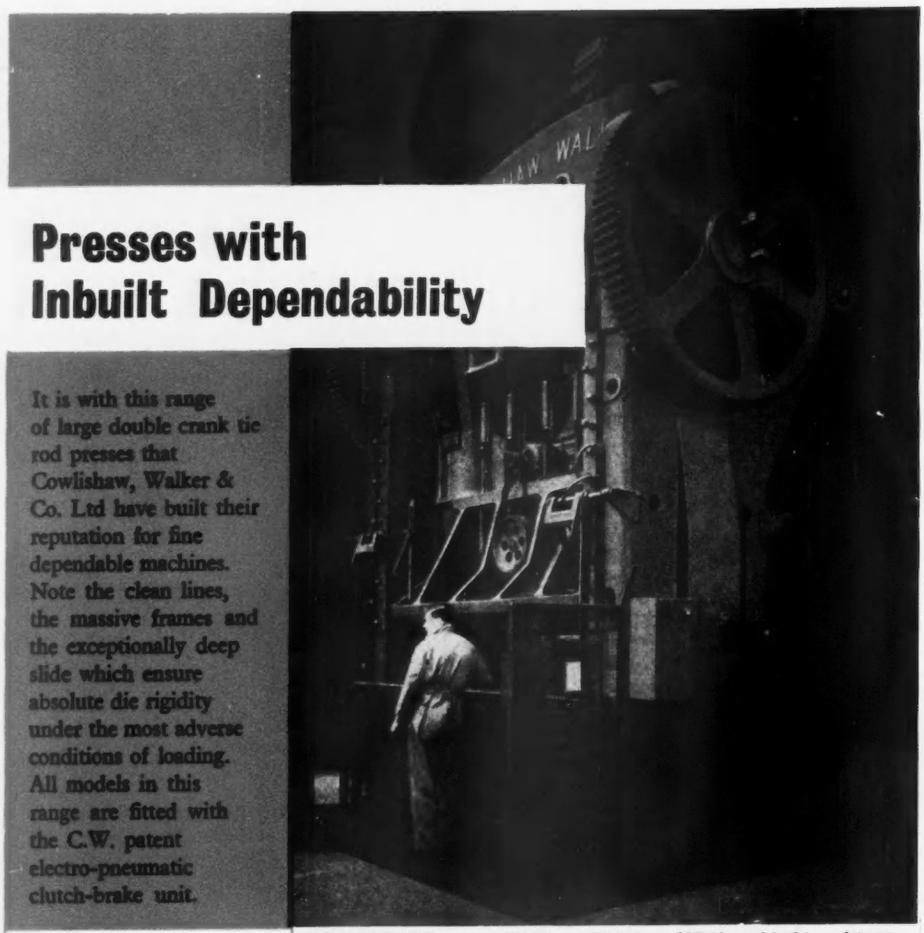

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BETWEEN SIDES ins.	75½	63	109½	109½	130½
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SLIDE F to B x R to L ins.	30 x 68½	42 x 54	54 x 99½	63 x 99	70 x 120
BED F to B x R to L ins.	36 x 72	60 x 61	60 x 108	76 x 108	70 x 129
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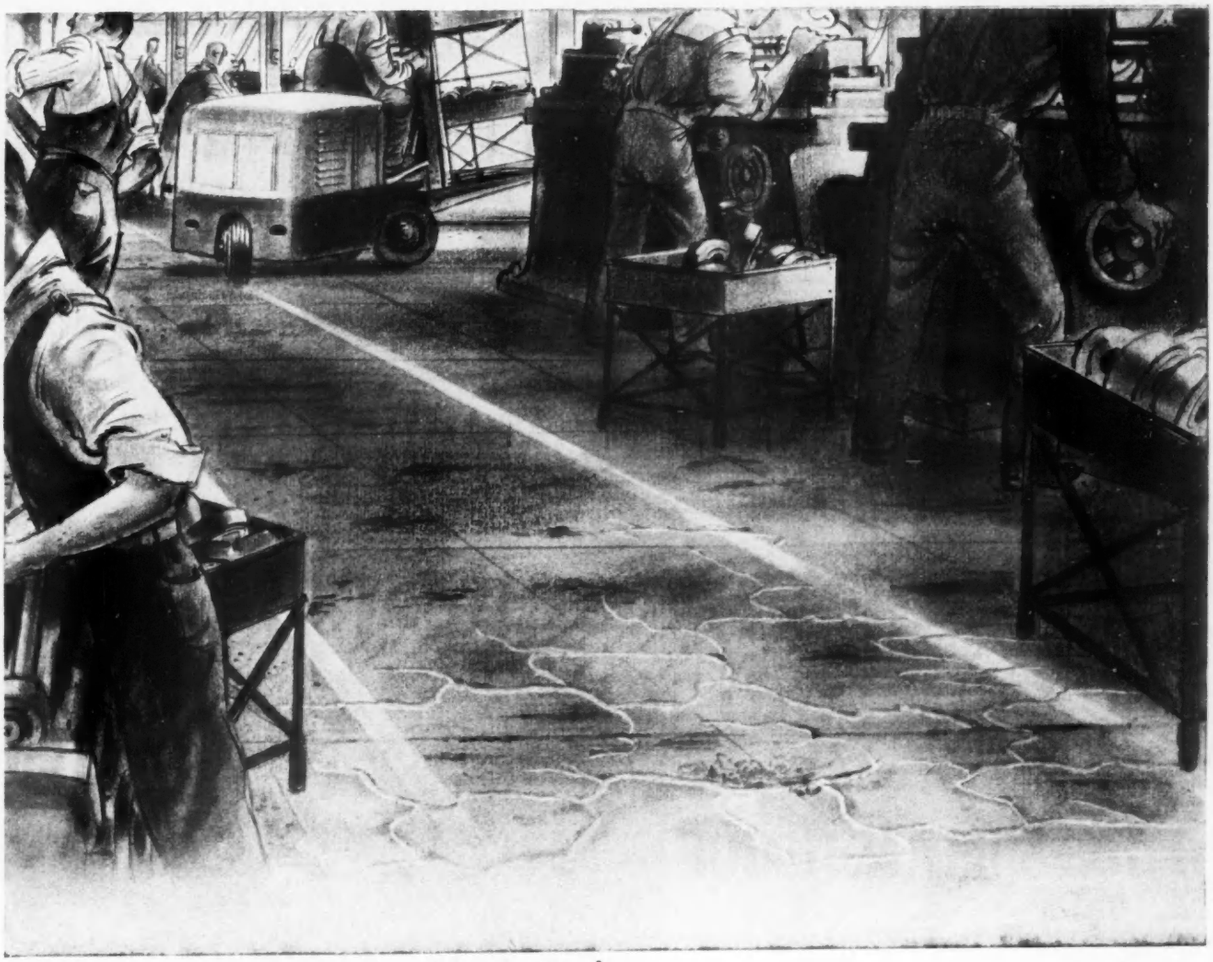

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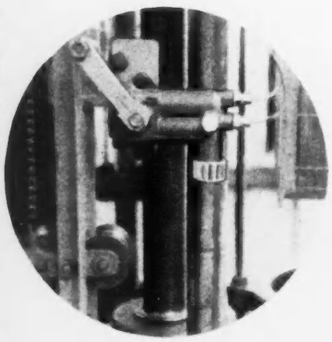

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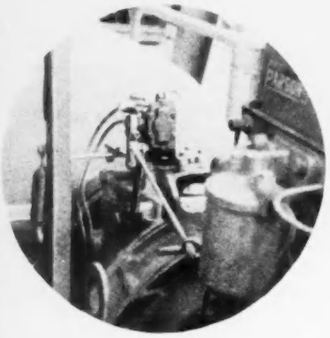

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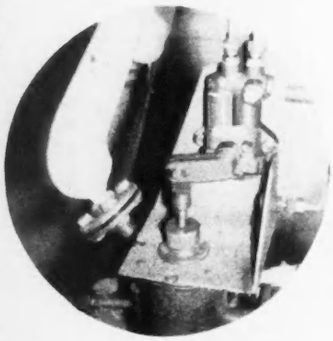

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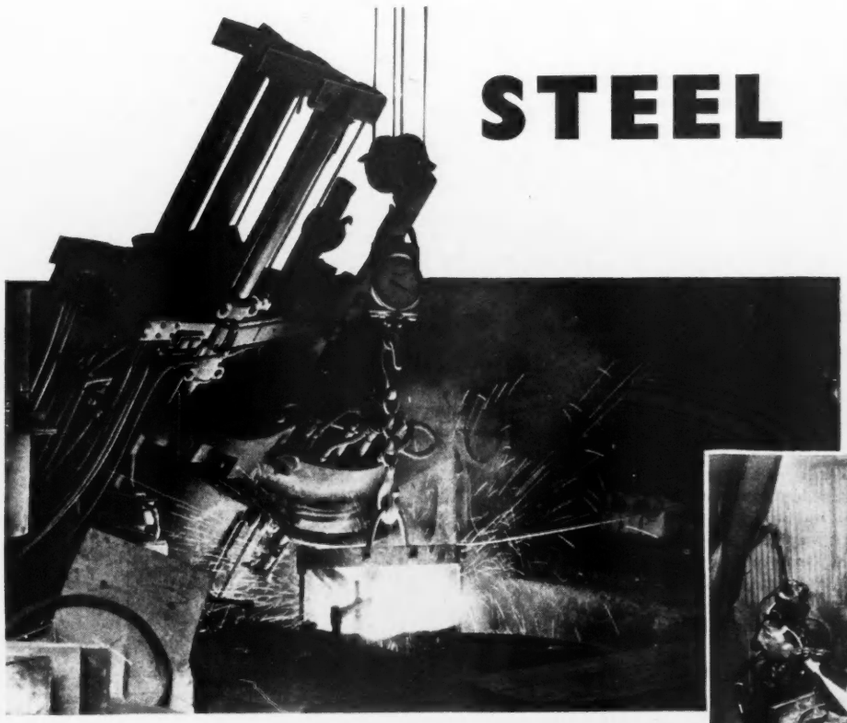

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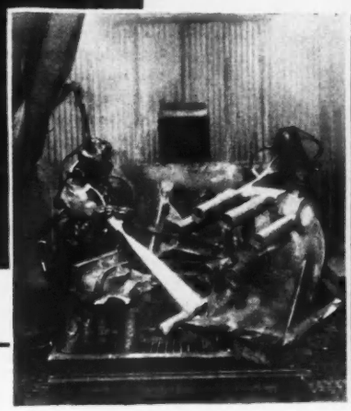

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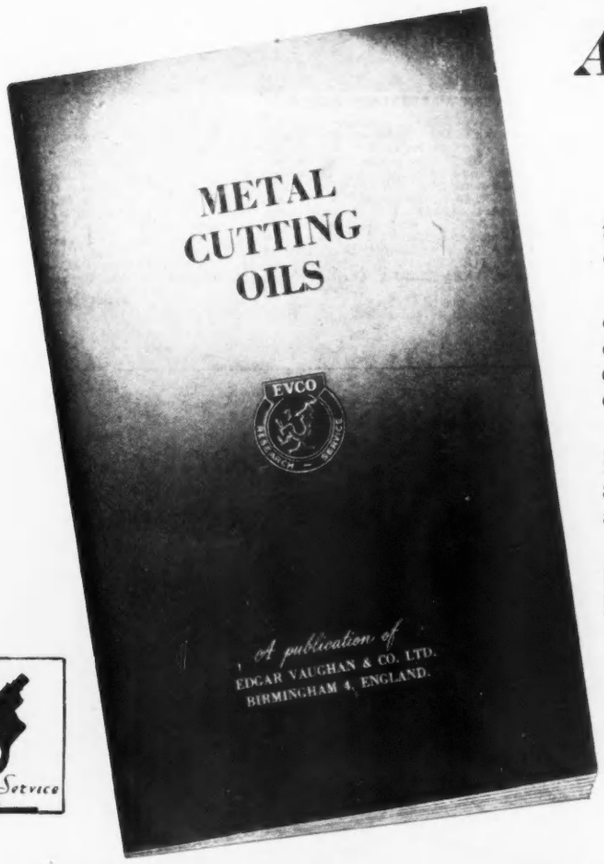

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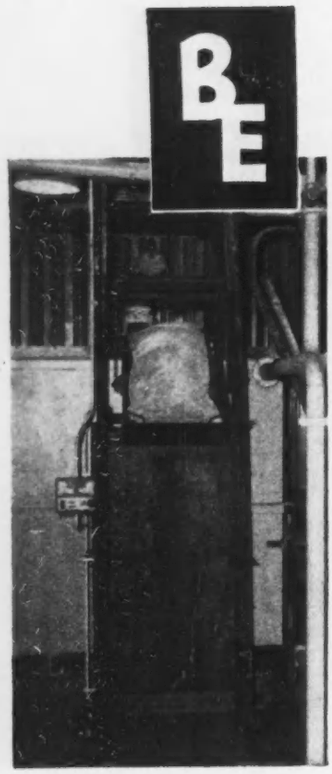

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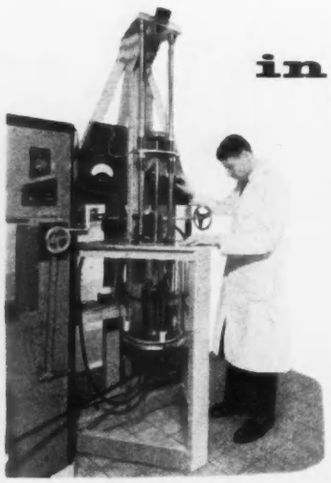

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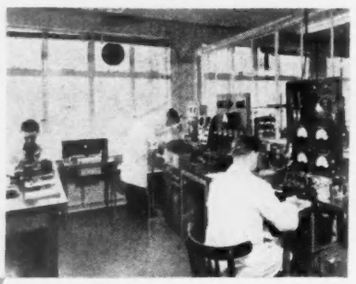

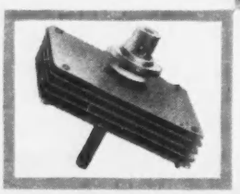

Illustrations.
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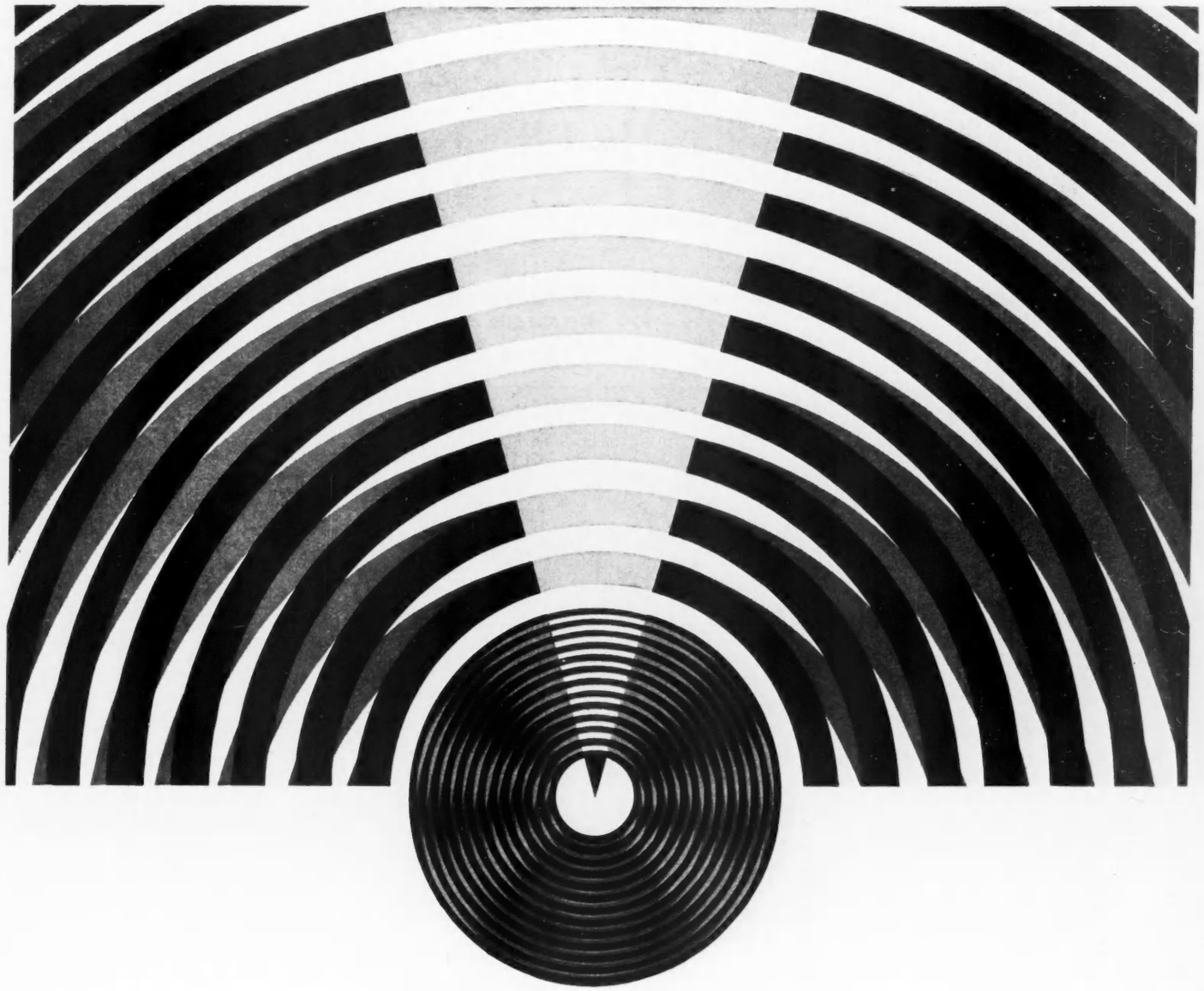

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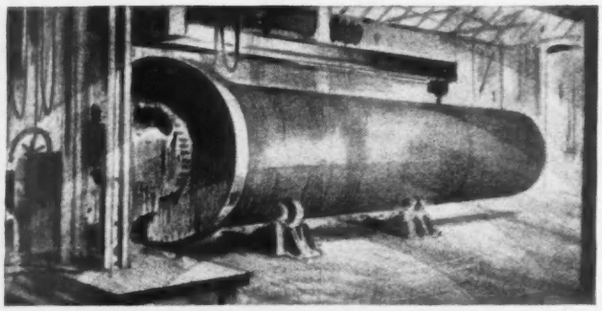

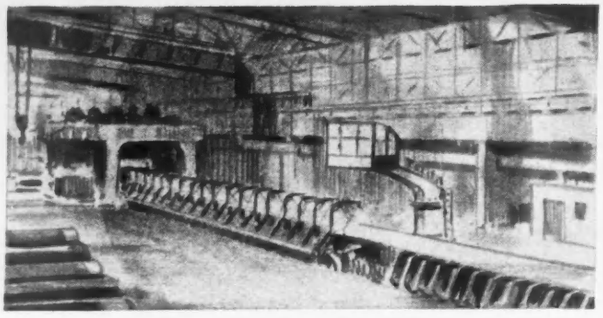

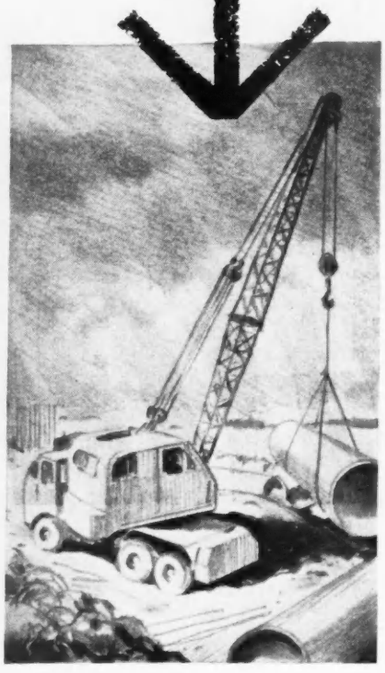

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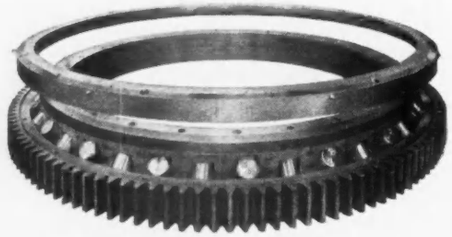

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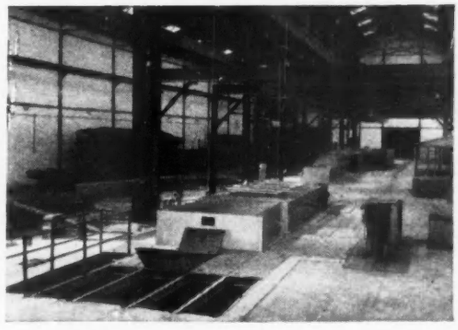

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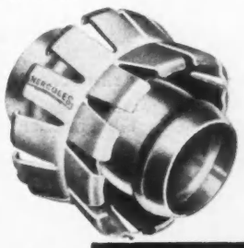

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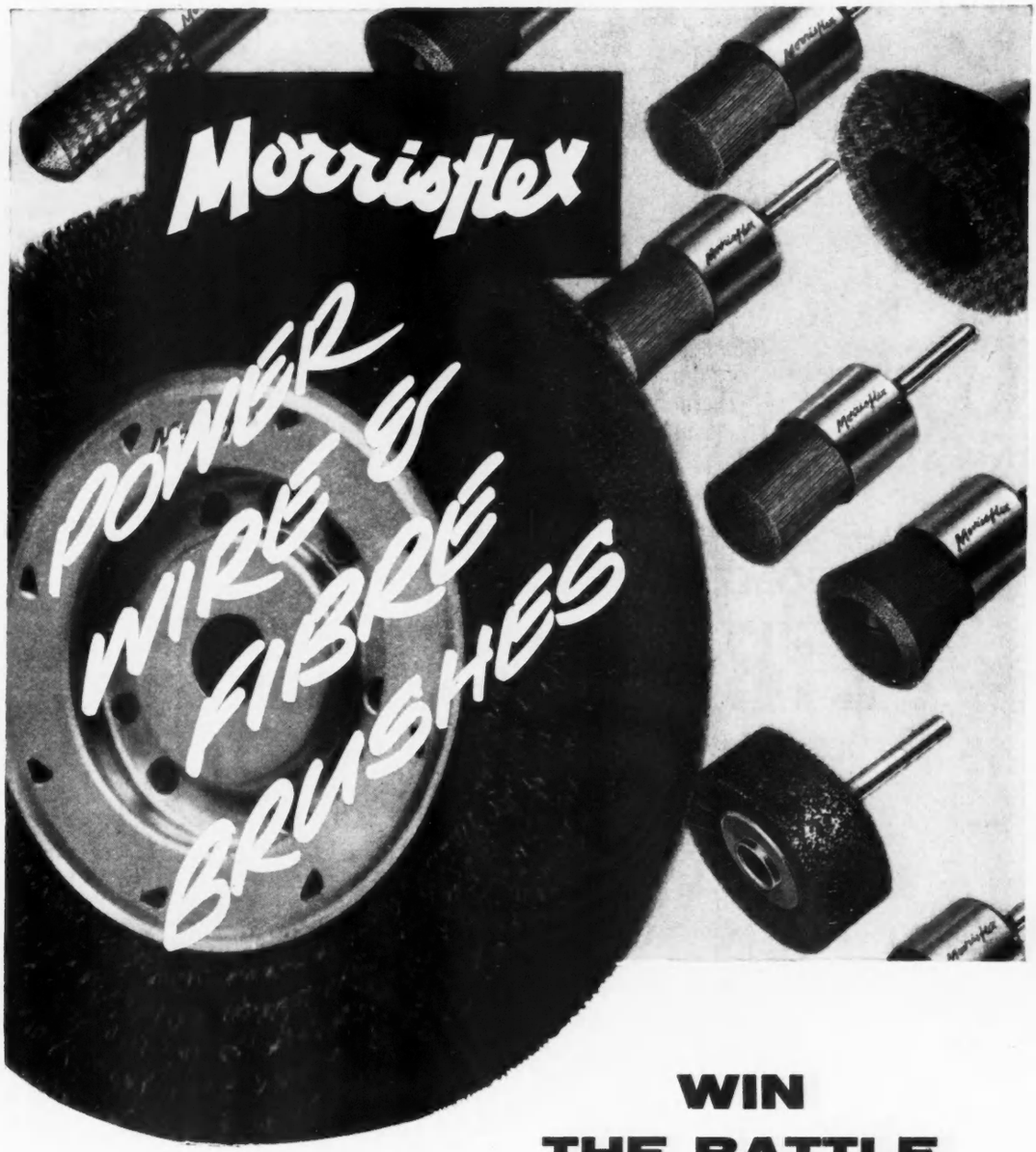

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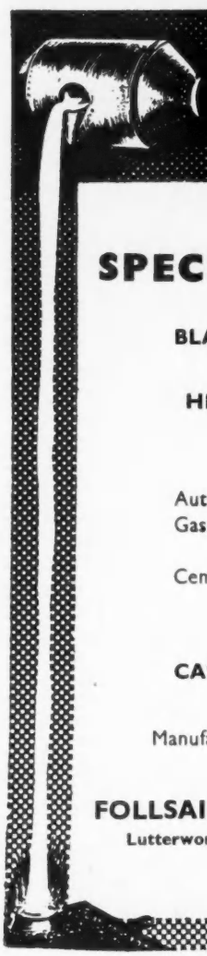

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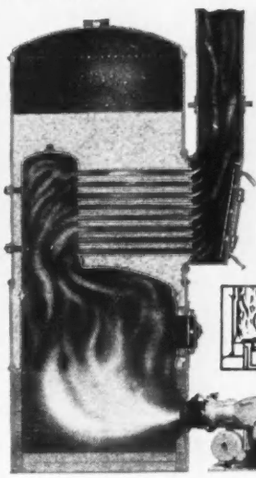

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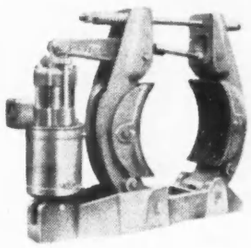

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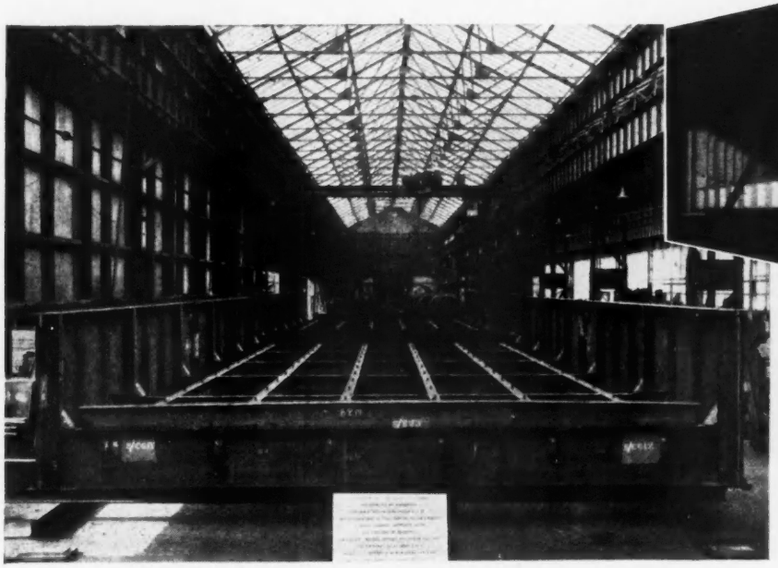

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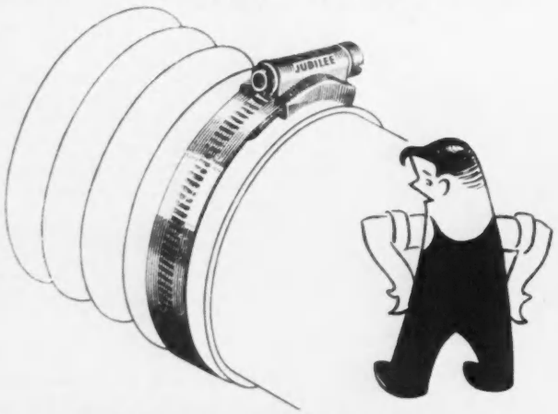

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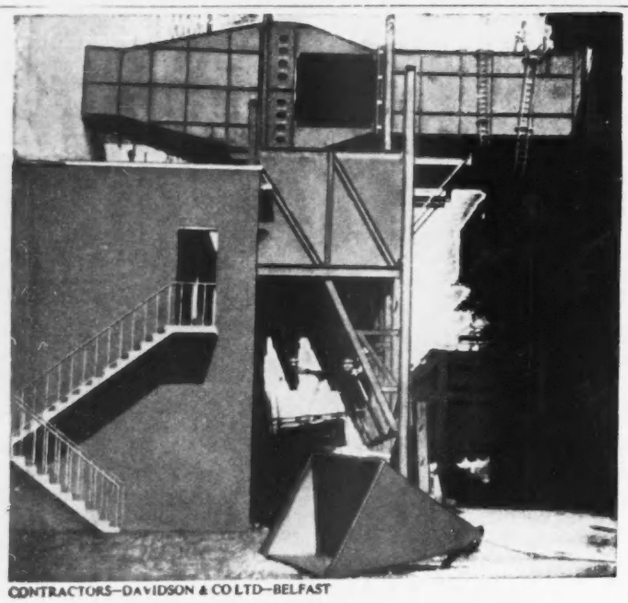

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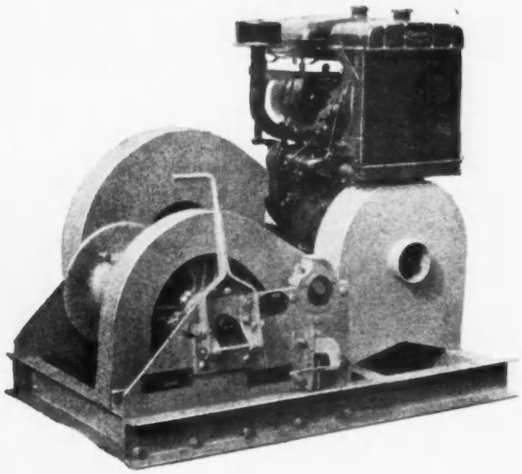

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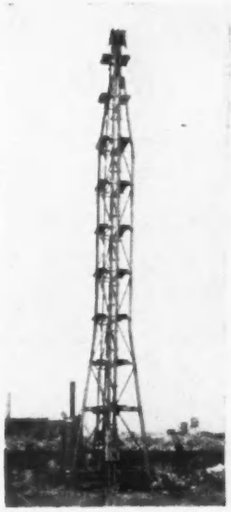

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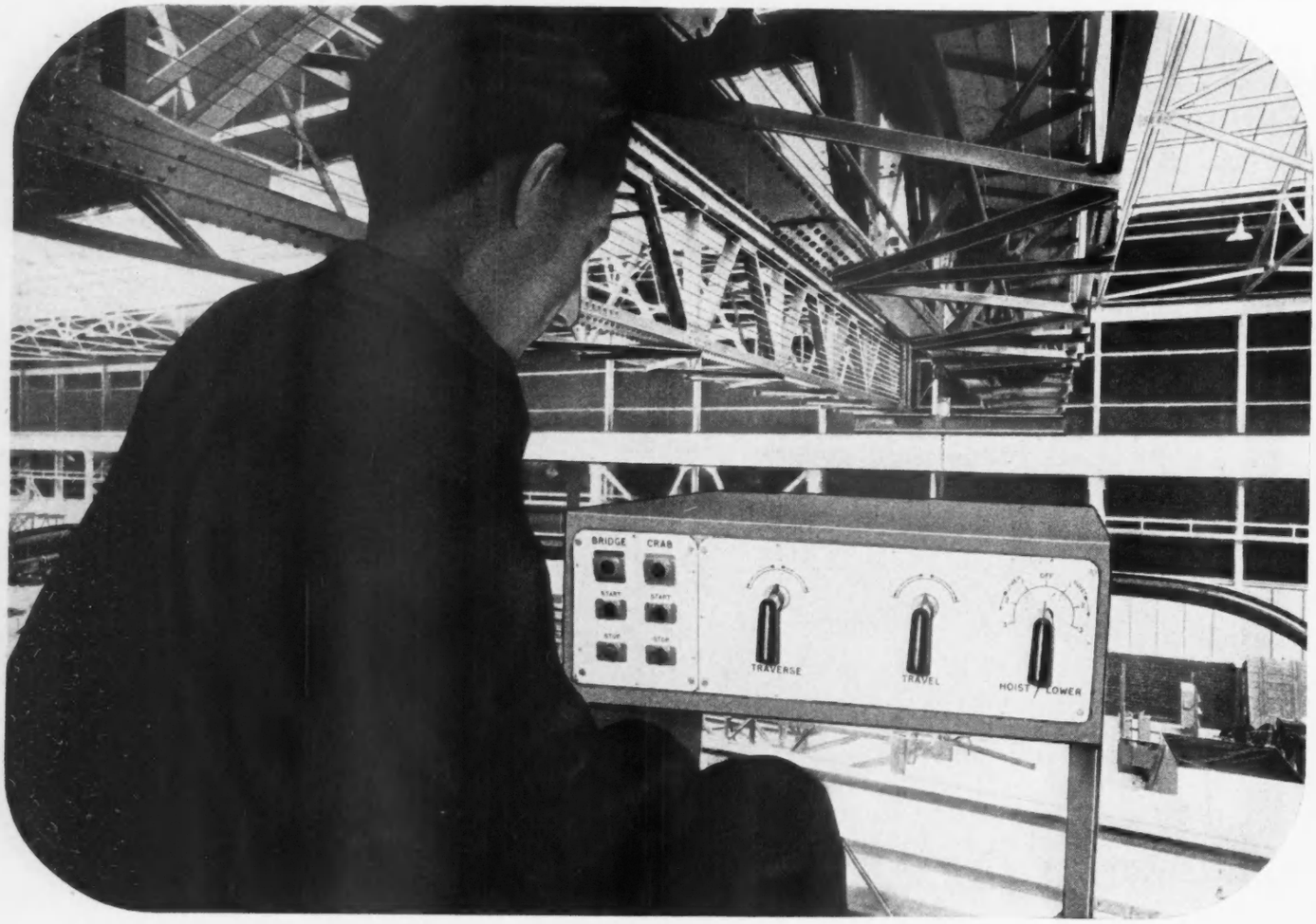

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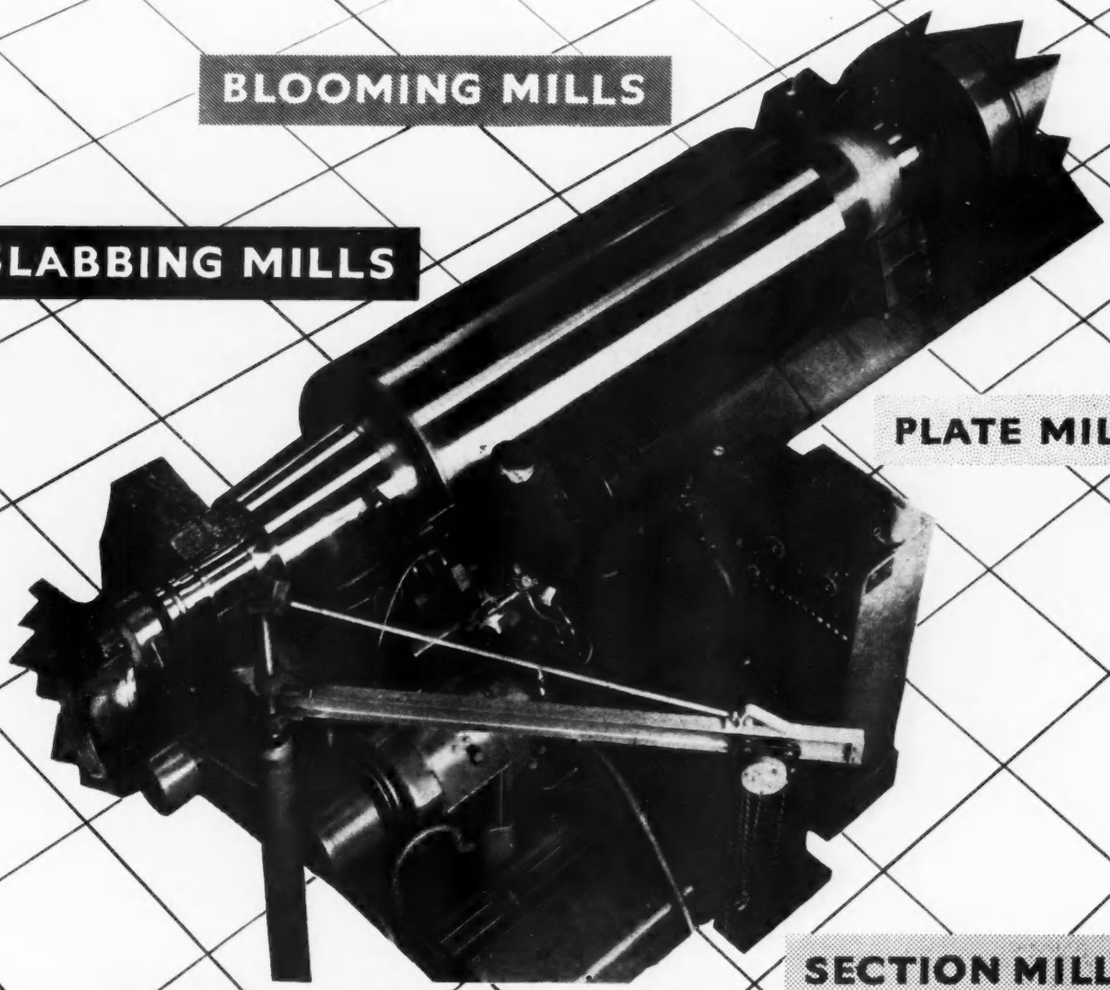

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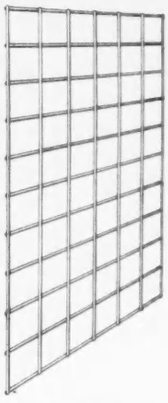

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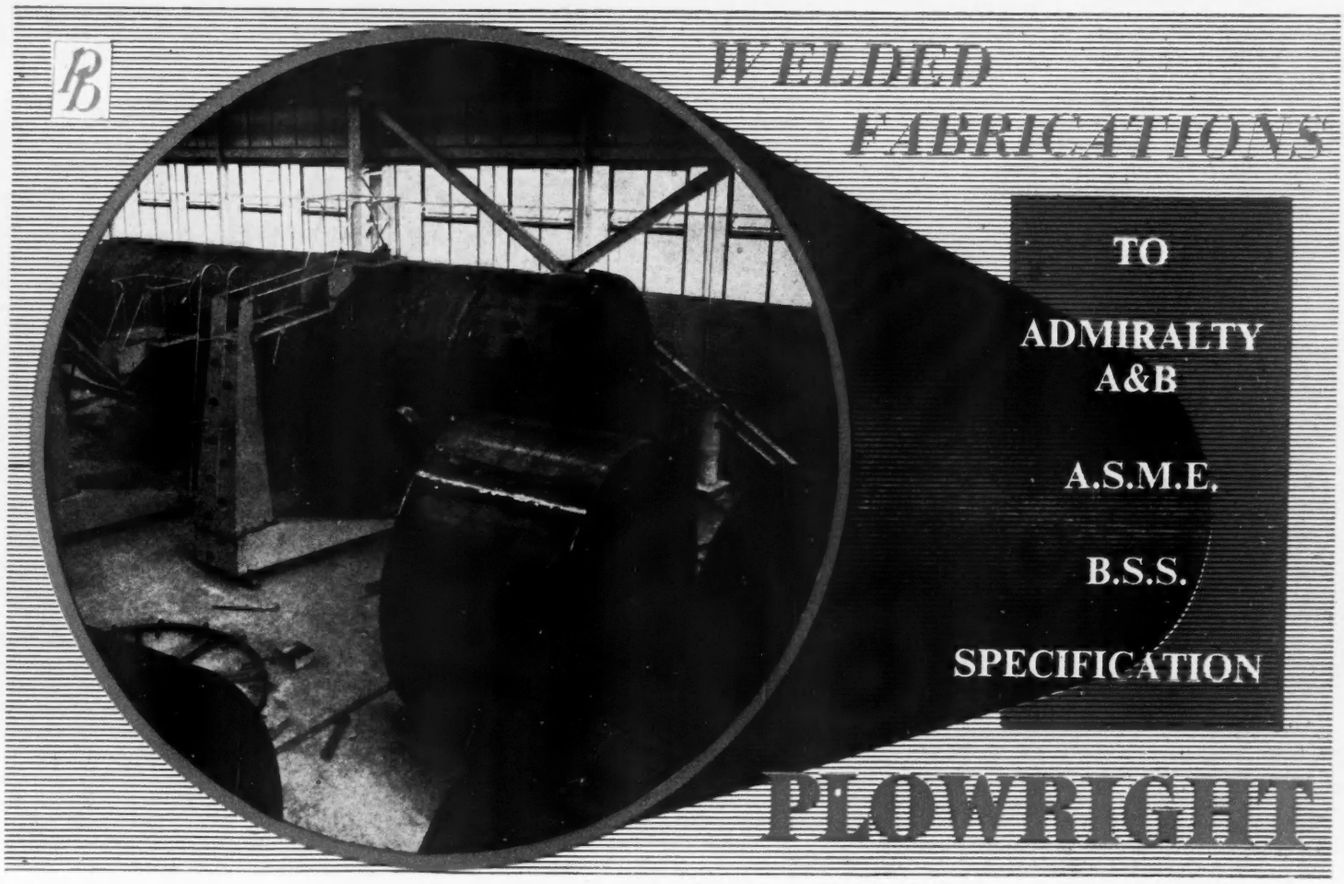

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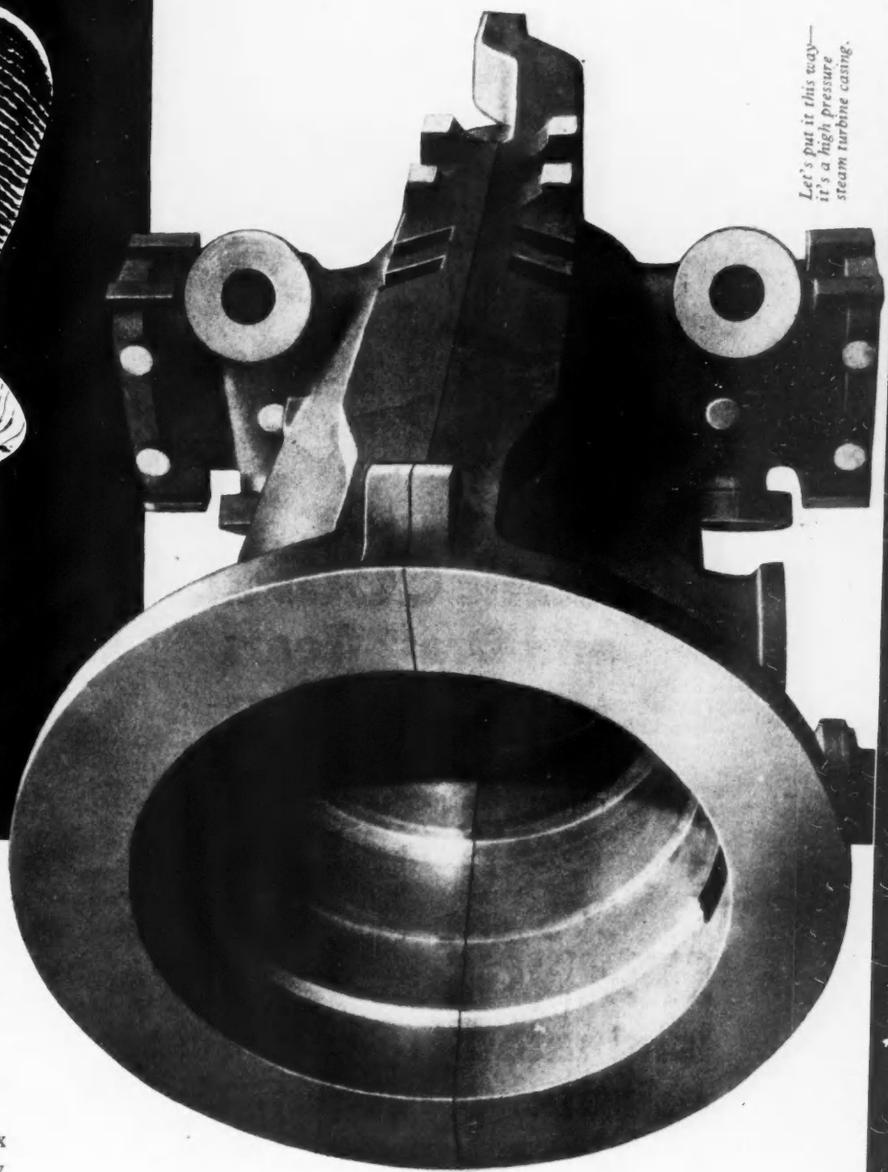

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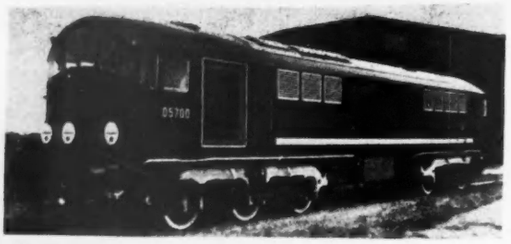

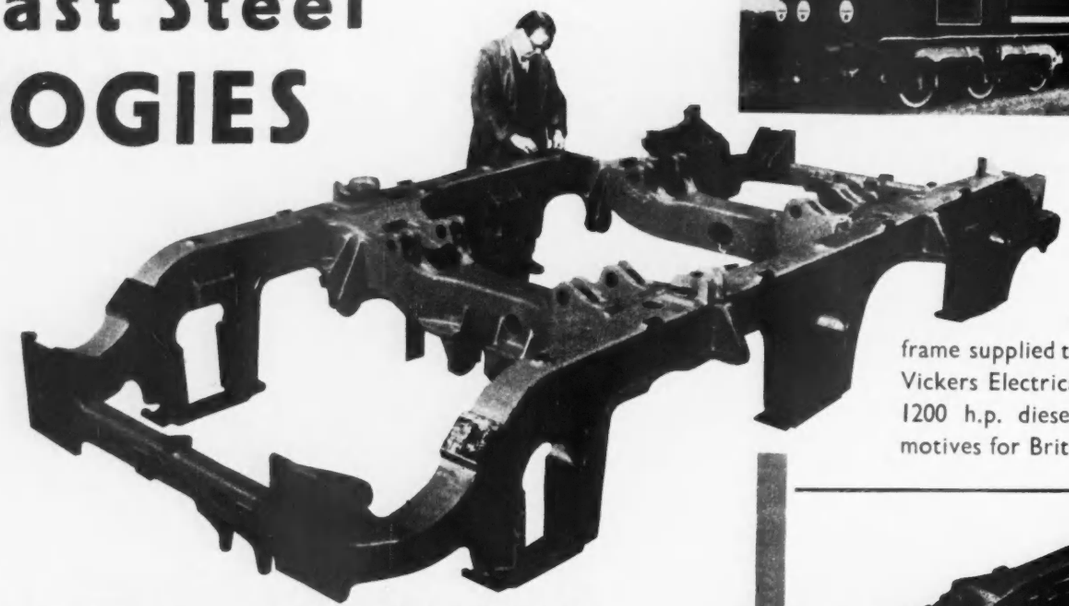

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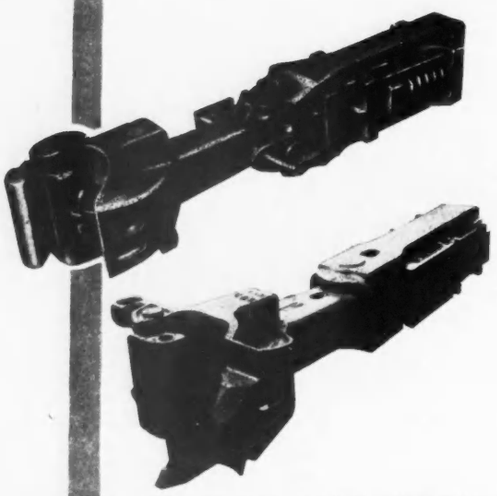

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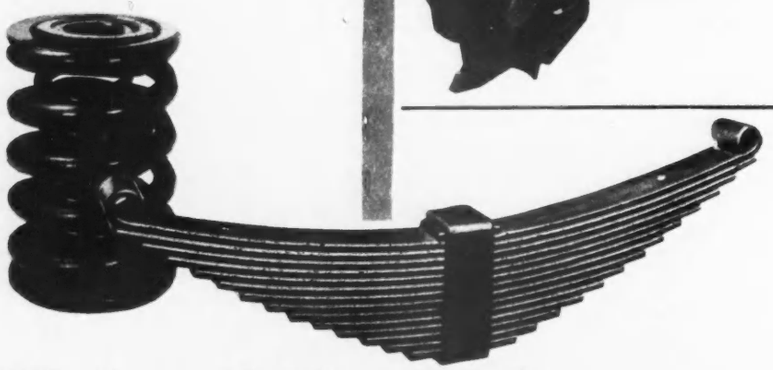

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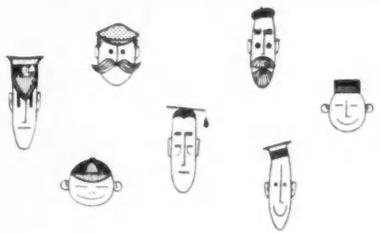

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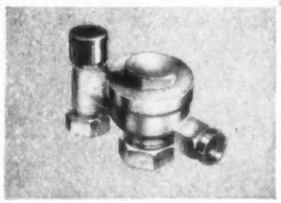

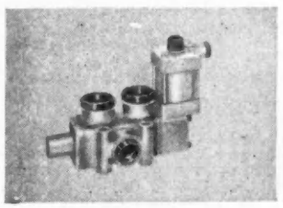

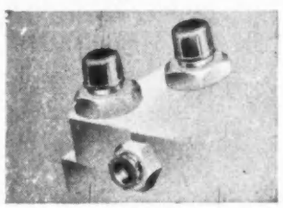

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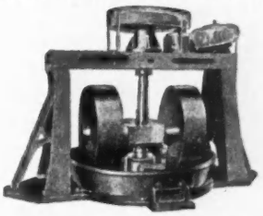

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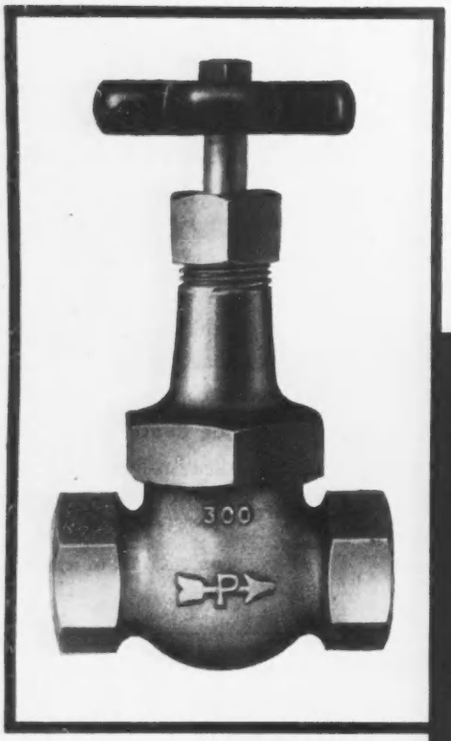

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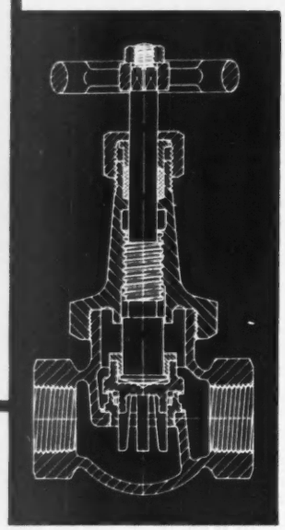

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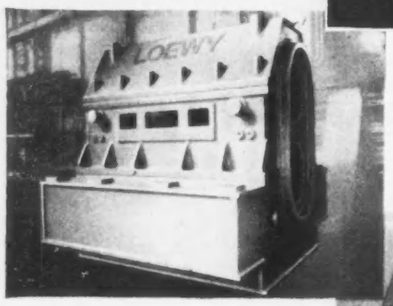

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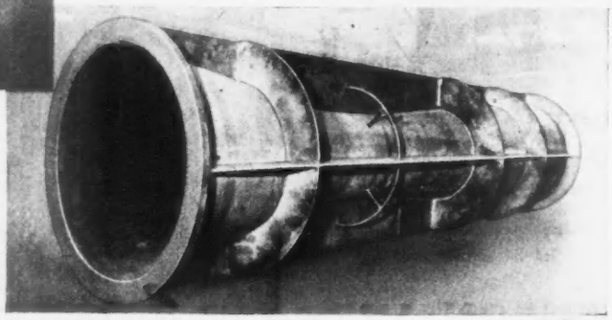

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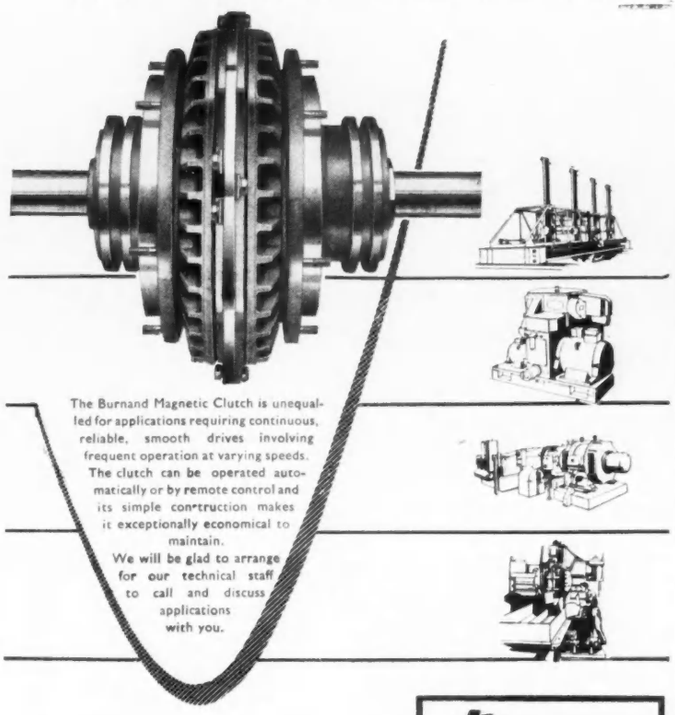

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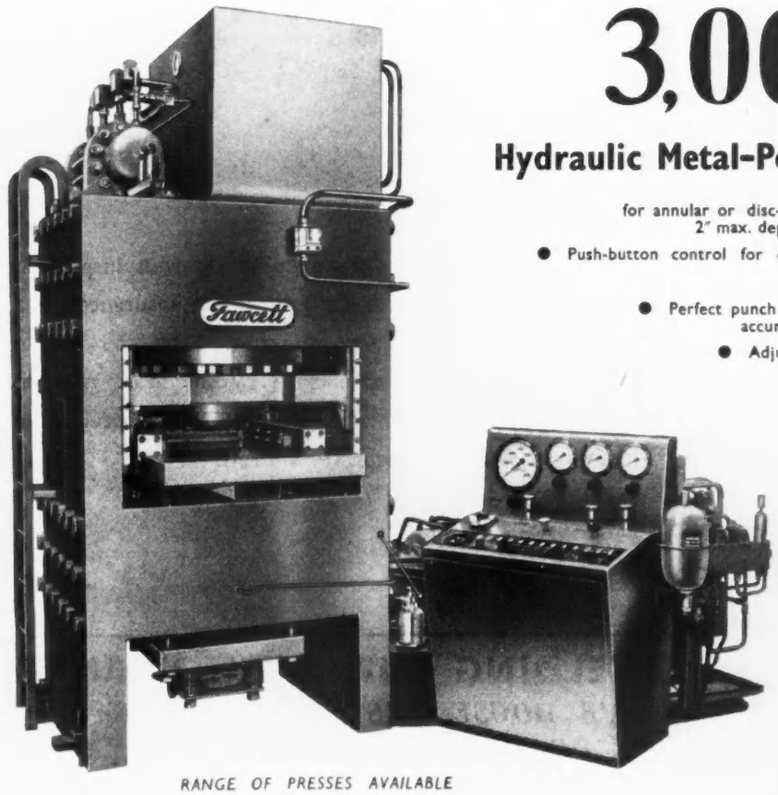

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Electrical Aids in Industry *Data Sheet* **No. 7**

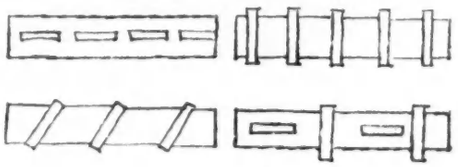
Lighting - 2

The general principles of factory lighting have been dealt with in the previous data sheet (No. 6). This one considers briefly certain factors — not always fully appreciated — that influence the lighting for some particular factory applications. The next data sheet will carry the subject further.

Work benches

The most universal application of lighting is to bench work, for there is no branch of manufacturing that does not have its work benches which, of necessity, are used for a great variety of occupations. No single lighting method is suitable for all cases.

The introduction of fluorescent lighting has gone a long way to solving one of the main problems here; for while the high degree of brightness of filament lamps tends to preclude their use for individual lighting owing to the glare, the fluorescent tube with its greater expanse of light source has made localised lighting with a low mounting height more practicable. Moreover, the length of the fluorescent tube puts into the hands of the designer a means of controlling shadows which, together with glare, probably represent the most prolific causes of errors and eye-strain.



With narrow individual benches (not more than 4 ft. wide), there are four basic methods of localised lighting : longitudinal, transverse, diagonal or a combination of longitudinal and transverse. With wider benches it is not advisable to use fittings directly over benches, and fittings should be behind the workers at each edge of the bench. Where particularly high illumination is required, fluorescent fittings may be mounted as local lights — low enough for the skirt of the reflector to conceal the lamps from the eye of the operator.

It is good practice to use reflectors which allow a reasonable amount of light to spill upwards, giving a certain amount of general lighting.

High-bay shops

Probably the most difficult of all factory lighting problems is that of high-bay lighting. In lofty, long and sometimes necessarily dirty shops such as those which house really large machine tools and overhead cranes, which do their worst to defy the efforts of the illuminating engineer, it requires great ingenuity, coupled frequently with high lamp wattage, to provide the workman with enough light to allow him to do his job efficiently. From the planer operator to the slinger, the workman, though he may not know it, is dependent on good lighting if he is to avoid an over-cut or a serious crane mishap.

The major problems associated with the lighting of high and relatively narrow shops, such as heavy machine shops and foundries, are :—

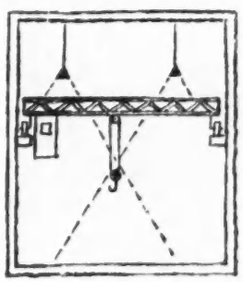
(a) Poor light utilisation caused by excessive light absorption by the large and often dark wall area.

(b) Preponderance of light flux downwards and poor cross lighting causing poor illumination on vertical surfaces, and heavy shadows.

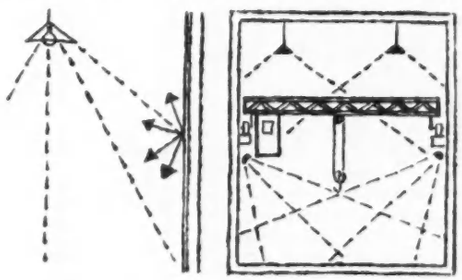
(c) Possibility of heavy light absorption in the atmosphere.

(d) Difficulty of access to high fittings for maintenance.

In high-bay workshops there is a tendency to use concentrating fittings so that the maximum proportion of the light output reaches the working area without spread to the walls, but the saving in wall absorption is obtained only by accepting a depressing environment, poor cross lighting and heavy shadows.



In many cases it is good practice to accept the inevitable reduction in light utilisation by wall absorption and to reduce this by applying light colours to interior surfaces where possible throughout. This approach results in more cheerful conditions and provides equally good illumination values and better cross lighting. Even better is to add angled lighting from the sides below crane level.



In the conditions obtaining in this type of shop, rapid deterioration in light source intensity due to dust must be expected. Facilities should always be provided for easy access to fittings for cleaning and maintenance.

For further information, get in touch with your Electricity Board or write direct to the Electrical Development Association, 2 Savoy Hill, London, W.C.2. Telephone : TEMple Bar 9434.

Excellent reference books on electricity and productivity (8/6 each, or 9/- post free) are available — "Lighting in Industry" is an example.

E.D.A. also have available on free loan in the United Kingdom a series of films on the industrial uses of electricity, including one on industrial lighting. Ask for a catalogue.

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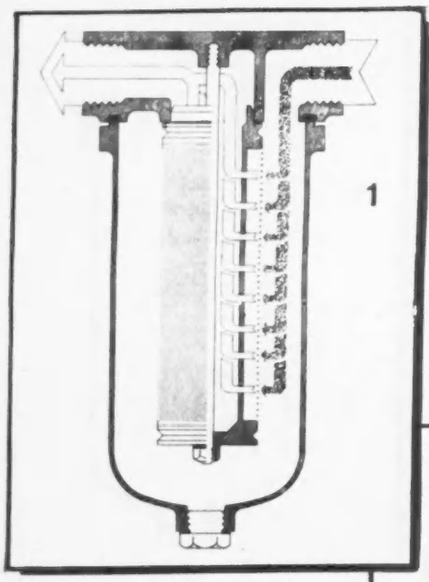
INSIDE INFORMATION

ON MODERN FILTRATION TECHNIQUES



AUTO-KLEAN LOLOS (1)

This is a range of filters incorporating wire-wound elements designed for ultra fine filtration of low to medium viscosity fluids under pressure.

Principle: A ribbed cylindrical former is screw cut, and a continuous monel or stainless steel wire is tightly wound into the grooves. By altering the pitch and/or the diameter of the wire defined alterations of mesh can be accomplished. LOLOS L.F. filters have a fabric sleeve fitted over a fine mesh wire-wound element.

Advantages: AUTO-KLEAN LOLOS filters ensure ultra fine filtration *with negligible pressure loss.* Their robust construction remains non-collapsible under extreme pressures, requiring practically no maintenance. Also important is its small lightweight construction.

Data: Working pressures can be arranged up to 2,000 lb/sq.in. Also included in the range are duplex and multi-element designs.

Typical Applications: Hydraulics; fuel and lubrication systems in air, sea and land transport, cooling circuits; distilleries; irrigation lines; washing and bottling plants, etc.

AUTO-KLEAN FLUSHFLO (2)

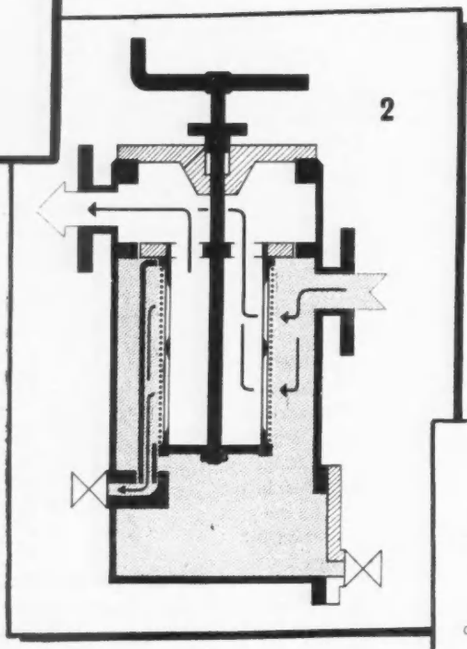
This is a range of self-cleaning filters specifically designed for continuous operation in the cooling and lubricating systems of heavy machinery.

Principle: Sludge collected by a wire-wound element is dislodged by reverse flow, while the filter element is electrically or manually turned. In contact with the wire element is a spring-loaded slotted tube which acts simultaneously as 'scraper' and discharge passage.

Advantages: The FLUSHFLO is completely self-cleaning while in service without interruption of liquid flow. It ensures fine, positive full-flow filtration with very low pressure losses. And, because the sludge is removed automatically without dismantling, its use leads to reduced maintenance costs. FLUSHFLO filters are also noted for their large capacities relative to size.

Data: Capacities and mesh dimensions fully tabulated in Auto-Klean literature. Quotations on request for processes and capacities not already covered.

Typical Applications: Large scale oil and water cooling circuits; hydraulics; washing plants; water treatment plants; machine lubrication, etc.



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The MICOM combines the advantages of paper as a clarifier with the efficient characteristics of an Auto-Klean, self-cleaning, plate-type element in a full flow filter.

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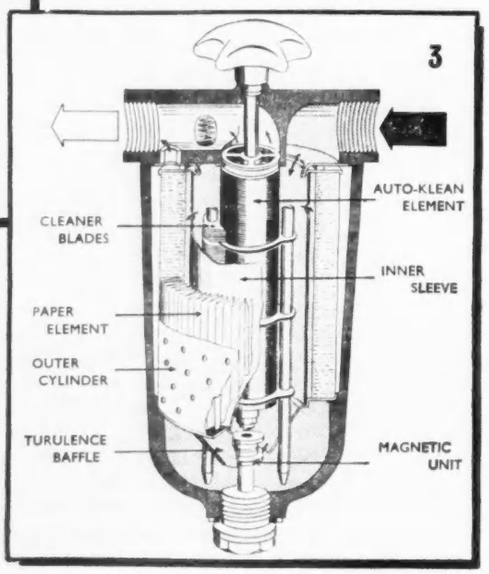
Advantages: Positive filtration is guaranteed despite build-up on paper element; paper cannot collapse through choking and therefore its lifetime is increased; constant pressure is maintained as build-up on paper increases . . . while the plate-type filter can be automatically cleaned by turn of the handle—without dismantling. Also important is the low pressure loss and small, lightweight construction of the MICOM.

Data: Working pressures up to 50 lb./sq.in. Can be supplied with ratchet gear for link drive from moving mechanism.

Typical Applications: Ideal for diesel engine lubrication systems of the medium horse-power range and other similar recirculatory applications.



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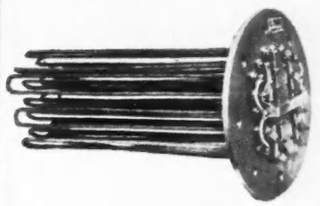

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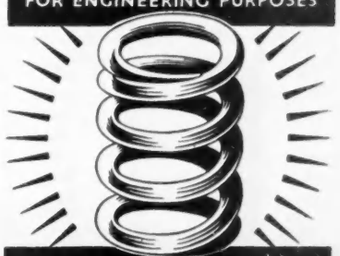

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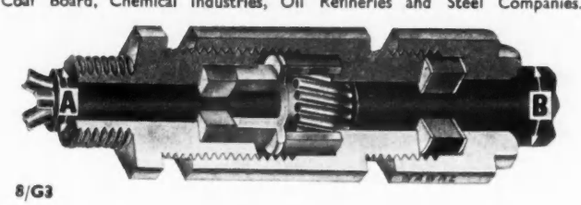
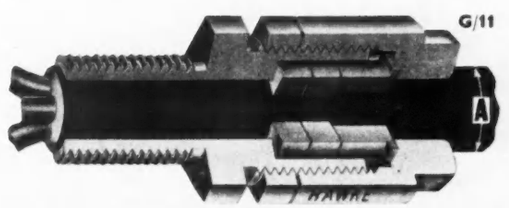


8/G3



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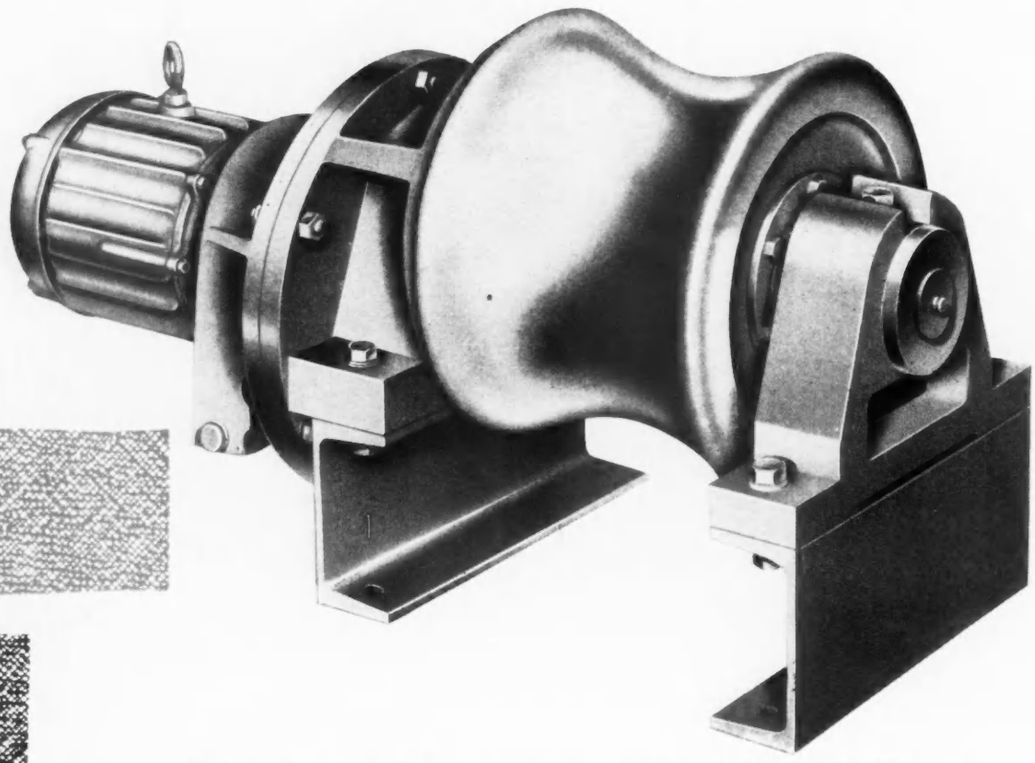

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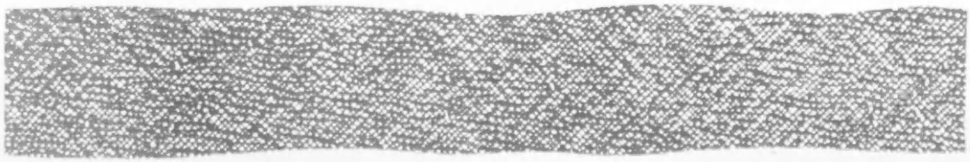
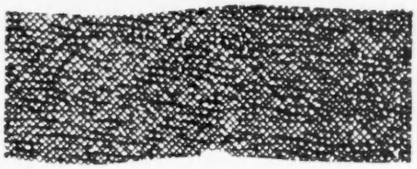
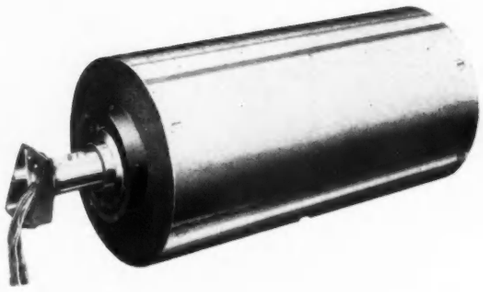




A typical installation incorporating a battery of Crofts variable speed skew roll group drives for conveying hot steel tubes



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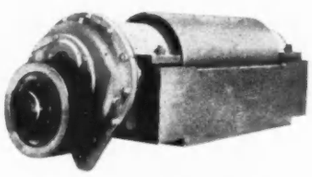
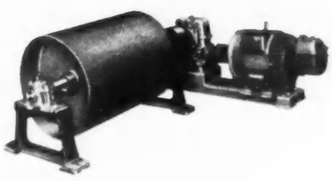
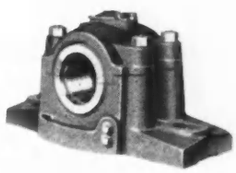


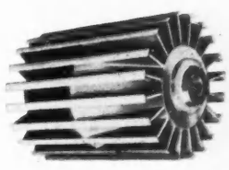
Shaft mounted gear driven Conveyor Rollers—Publication 157/K



Conveyor Drives—Publication 858/K



Plummer Blocks, plain, ball or roller bearings—Publication 5734/K



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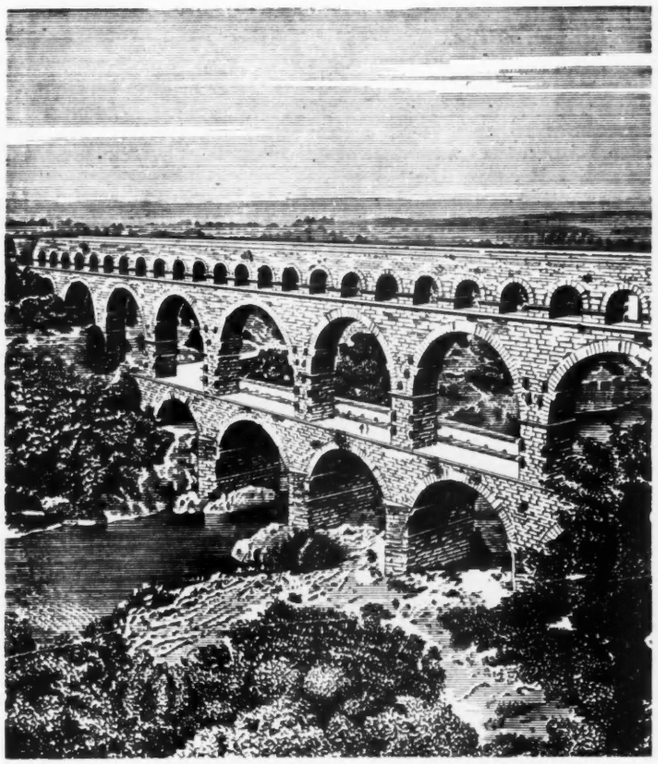

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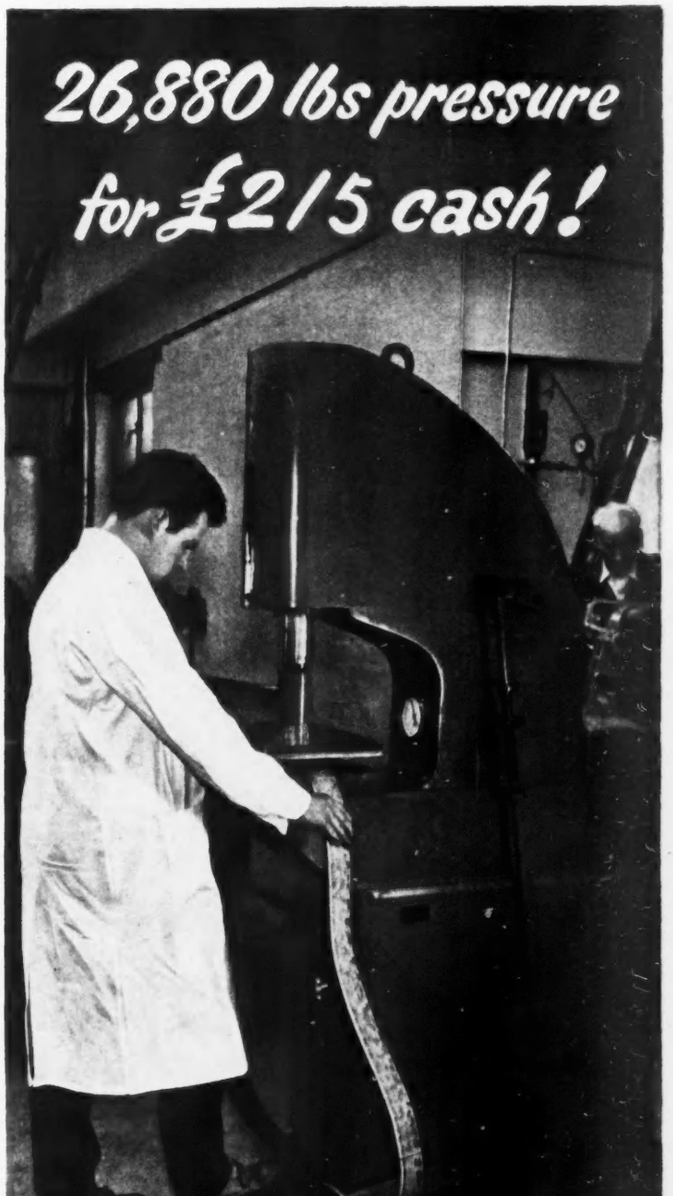

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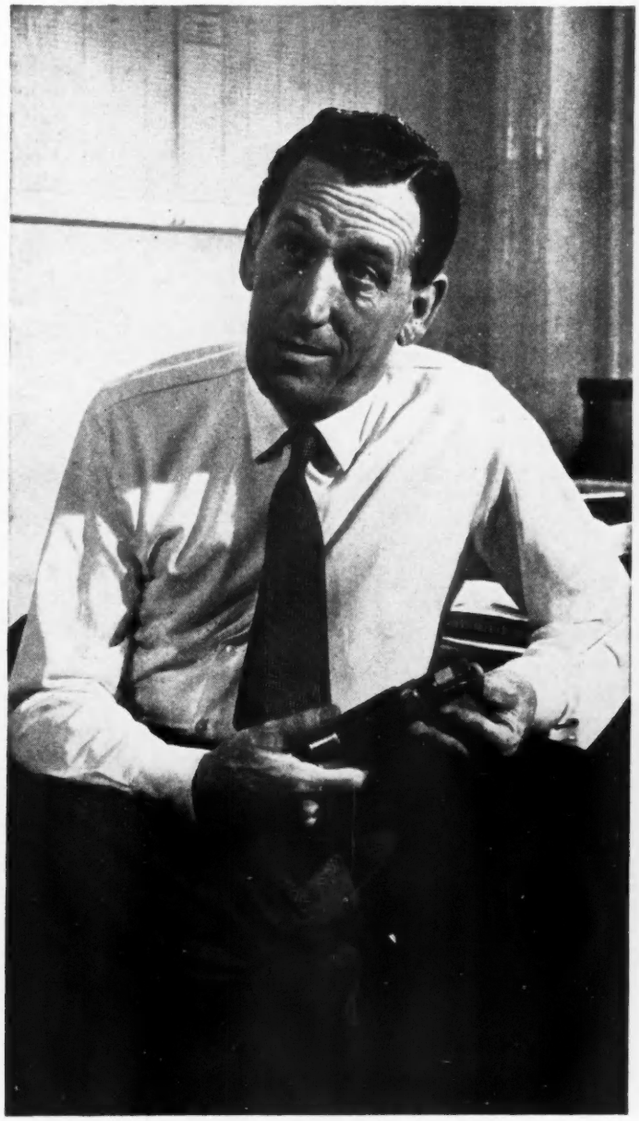

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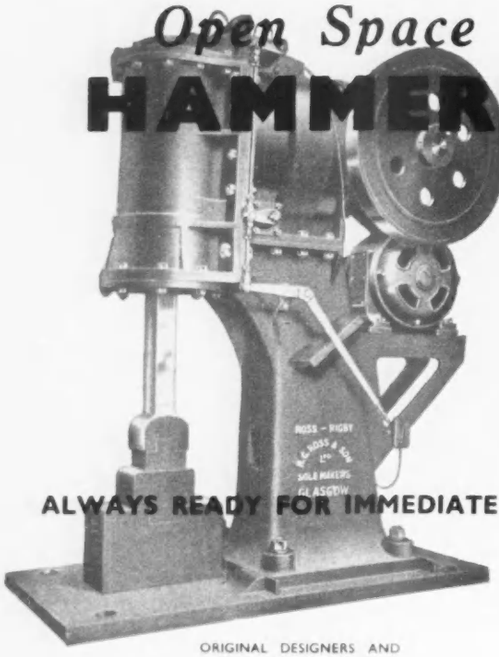

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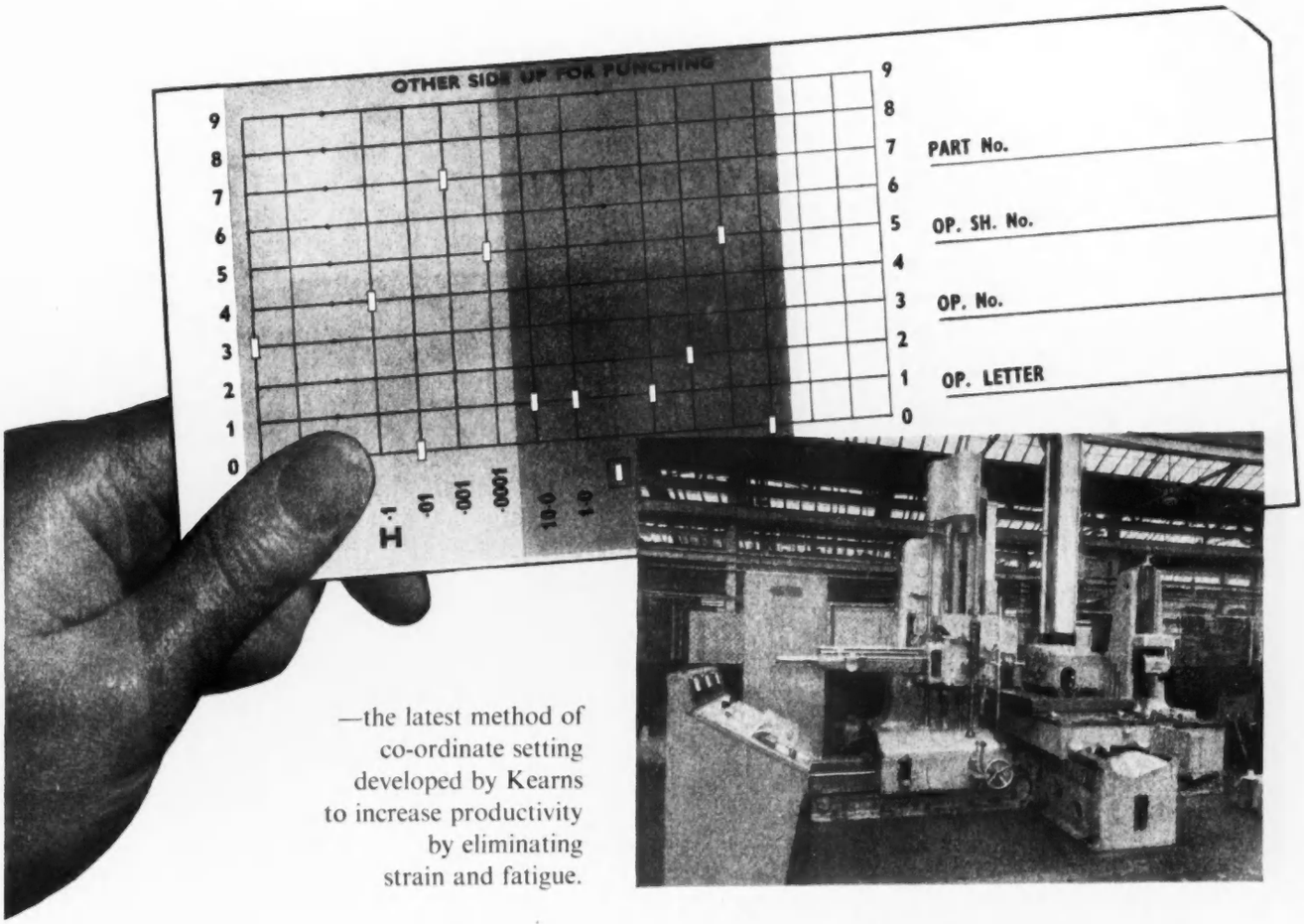

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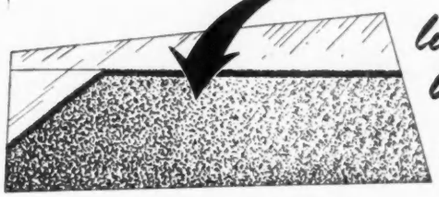

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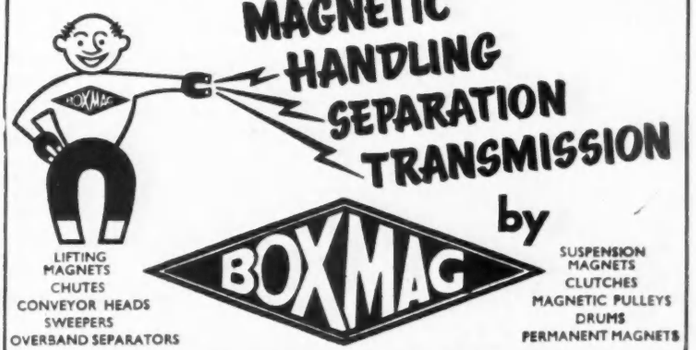

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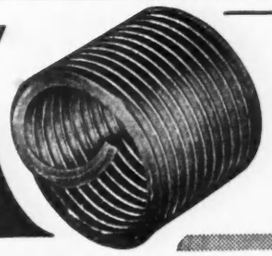

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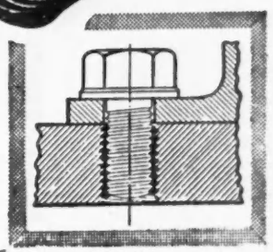

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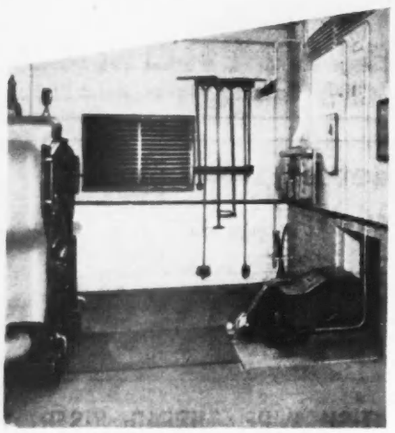

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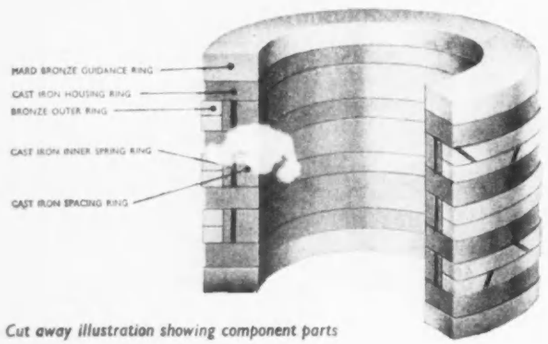

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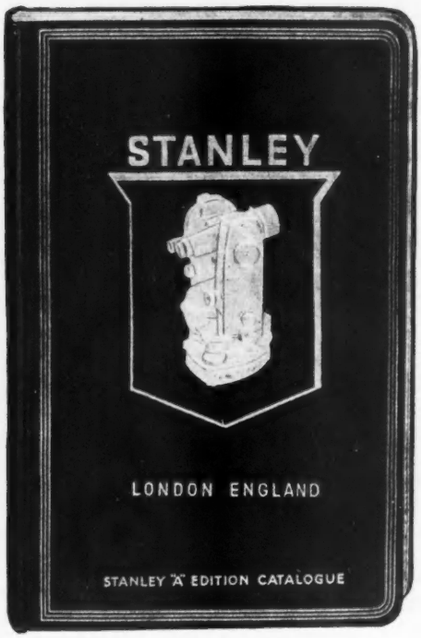

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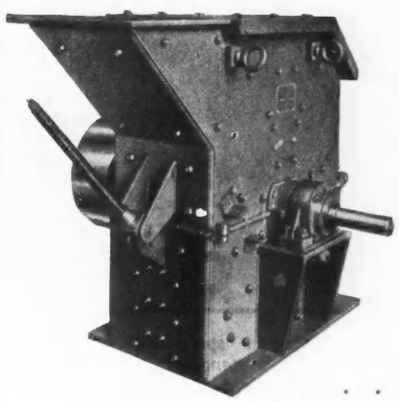

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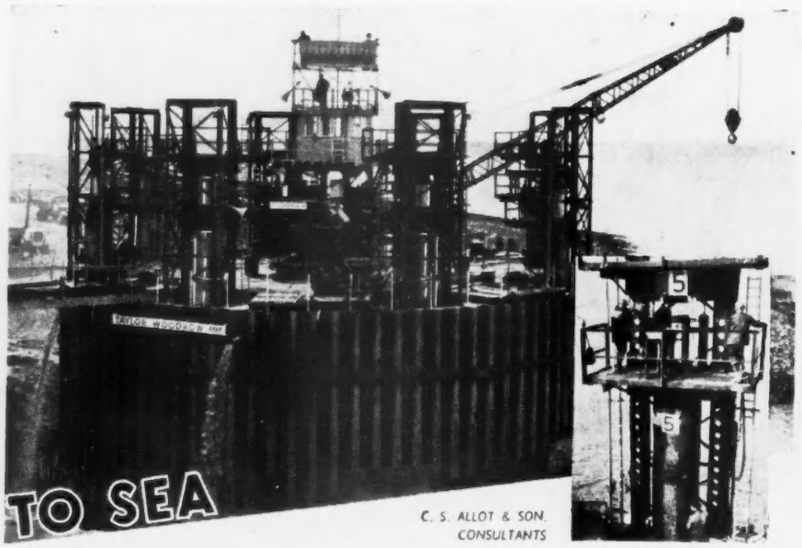

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No formula defined the experience which governs the high quality of our production. No text book advised the enterprise which has made our resources a byword in this modern world. No written guide has stipulated that pride and skill should be our hallmarks.
Not in the book — but these are the qualities which have made J.M.I. leaders in the manufacture of every conceivable type of steel casting.
J M I
STEEL CASTINGS
Jarrow Metal Industries Ltd,
Western Road, Jarrow, Co. Durham
Tel: Jarrow 89:7111
Subsidiary Company of
Armstrong Whitworth (Metal Industries) Ltd,
Close Works, Gateshead upon Tyne 8

Enter No. 1251 on reply card

Bronze

for hard wear and low friction

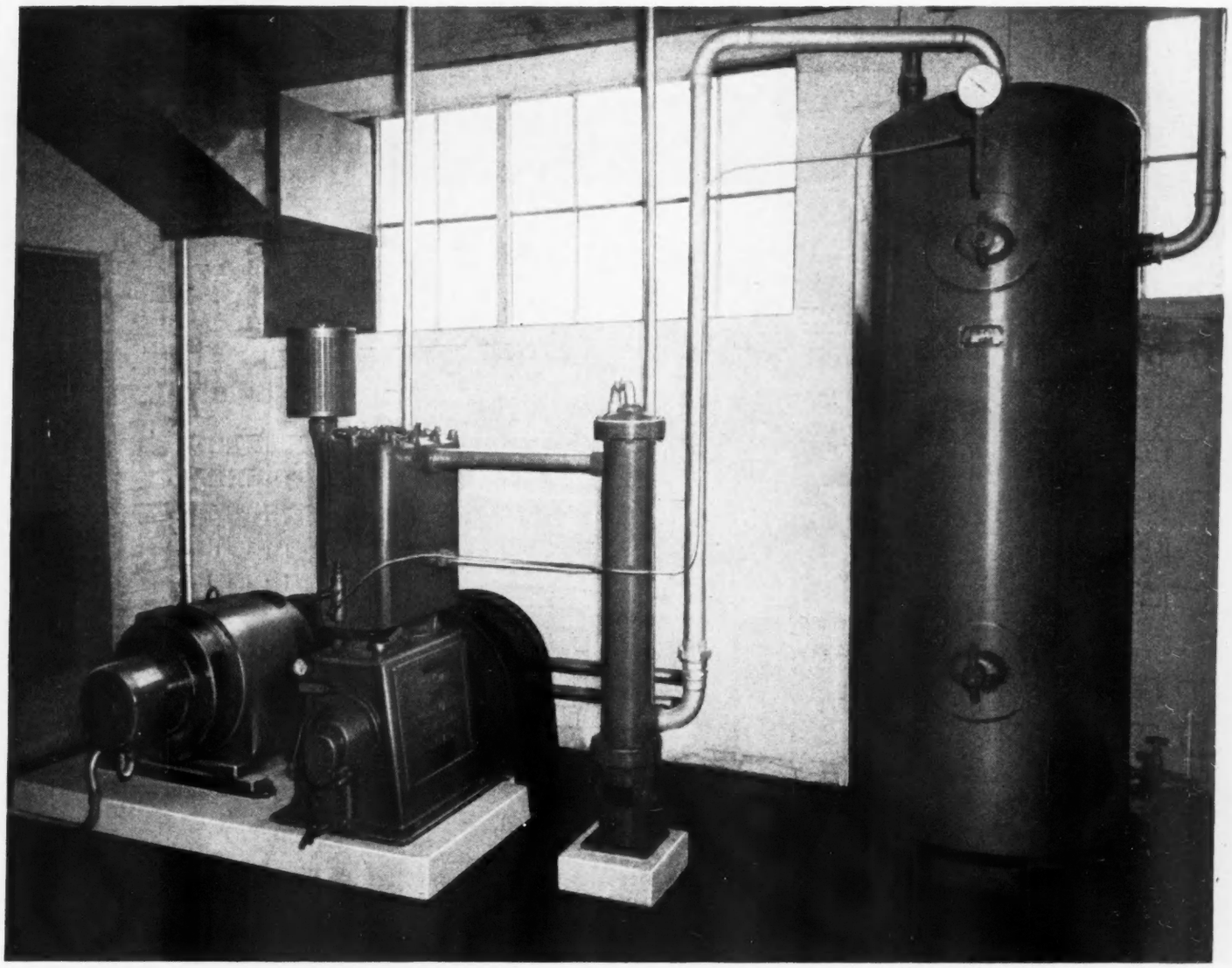
Holfos is a bronze made only by Holroyd. We first brought it out thirty years ago and since then we have constantly been improving and perfecting the technique of its production.

Its use is a distinct contributory factor to the high efficiency and sturdy performance of Holroyd worm gears and worm gear speed reducers. Holroyd worm gears using Holfos bronze hold the World Record for efficiency as determined by an independent test made at the National Physical Laboratory.

Holroyd

JOHN HOLROYD & CO LTD
HOLFOS WORKS ROCHDALE
(For Castings and Machined Blanks)
PERSEVERANCE WORKS MILNROW
(For Finished Gears)

Enter No. 1261 on reply card



Photograph by courtesy of Luxram Electric Ltd.

"BROOMWADE" OIL-FREE Compressed Air helps make Luxram Electric Lamps

A "BROOMWADE" C 660 Carbon Ring Air Compressor supplies the **oil-free air** needed to process the filaments of Luxram electric lamps.

Wherever oil-free air is essential—for instance, in chemical and food processing and instrument control—you can depend on the C 660. It is economical, efficient and reliable, with an output of 100 cu. ft. per minute at 100 lb. per sq. in. pressure.

Write for full details.

"BROOMWADE"

AIR COMPRESSORS & PNEUMATIC TOOLS

Your Best Investment

BROOM & WADE LTD., P.O. BOX No. 7, HIGH WYCOMBE, ENGLAND. *Telephone : High Wycombe 1630 (10 lines) Telegrams : "Broom", High Wycombe. (Telex)* 661 SAS

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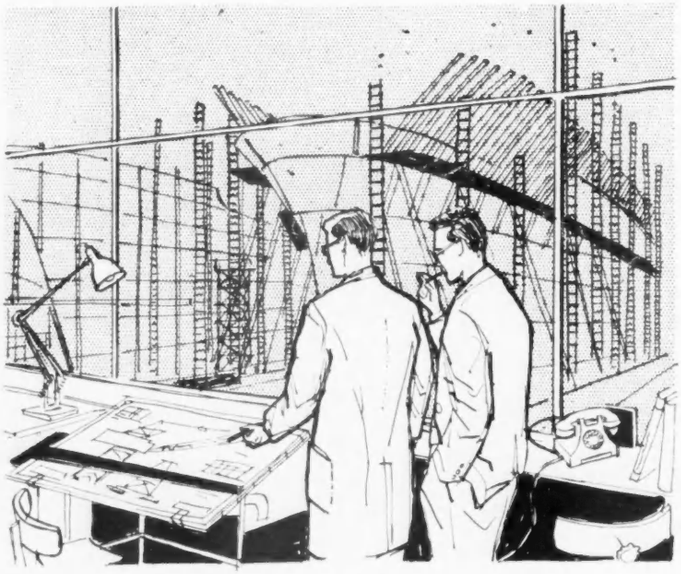
planning for progress

Cowans Sheldon engineers are constantly searching for new solutions to lifting problems. By using the most recently proved methods and materials, they produce cranes of every type and capacity, purpose-built for a multitude of duties.

This new design is for an electrically driven rope luffing travelling crane for shipyard and dockyard service.



COWANS SHELDON & CO LTD

CARLISLE ENGLAND Telephone: CARLISLE 24196-8

LONDON OFFICE: *AFRICA HOUSE KINGSWAY WC2 TEL: HOLBORN 0268*

P.3402

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High Grade Soft Grey Iron & Non Ferrous Castings

PATTERN MAKING

TYSELEY FOUNDRY LTD.

Wolverhampton Office:
BUSHBURY WORKS,
WOLVERHAMPTON
Telephone 21455

Telephone:
ACOCKS GREEN 1283
Telegrams:
Tyseley Foundry B'ham.

JAMES ROAD, TYSELEY,
BIRMINGHAM, 11

For the General Engineering, Machine Tool & Electrical Trades

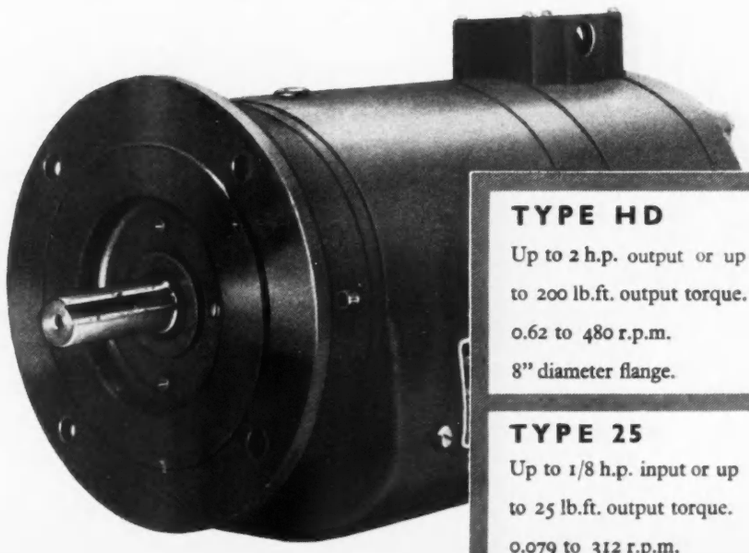
Enter No. 1291 on reply card

flange mounting geared motors

All NECO co-axial geared motors can be supplied with flange mounting instead of feet to enable the unit to be bolted accurately to your machine.

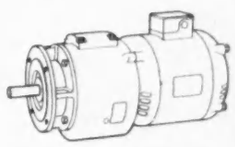
TYPE DS

Up to 1/2 h.p. input or up to 100 lb.ft. output torque. 0.5 to 475 r.p.m. 8" diameter flange. Removable feet can be supplied with this unit.



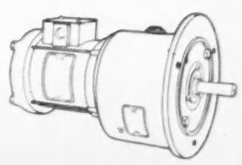
TYPE HD

Up to 2 h.p. output or up to 200 lb.ft. output torque.
0.62 to 480 r.p.m.
8" diameter flange.



TYPE 25

Up to 1/8 h.p. input or up to 25 lb.ft. output torque.
0.079 to 312 r.p.m.
8" diameter flange.



NECO TRADE MARK

FOR ALL SLOW SPEED DRIVES

NECO GEARED MOTORS LIMITED · 204 QUEENSTOWN ROAD · LONDON · SW8
Subsidiary of Normand Electrical Co. Ltd. *Telephone: MACaulay 3211-4*

Enter No. 1292 on reply card

ENGINEERING AND
TECHNICAL FACILITIES
TO ENSURE QUALITY
AND CONTROL AND TO
PROVIDE SERVICE ON
CASTING DESIGN AND
TECHNICAL MATTERS

METALLURGICAL CONTROL
HIGH DUTY GREY IRON
HIGH STRENGTH & GOOD STRUCTURE
WEAR RESISTANCE
WITH FREE MACHINEABILITY

SAND CONTROL
DIMENSIONAL ACCURACY
SMOOTH FINISH

QUANTITY PRODUCTION
CAPACITY

SERVICE

C & B SMITH
LIMITED
IRONFOUNDERS
WOLVERHAMPTON

CBS

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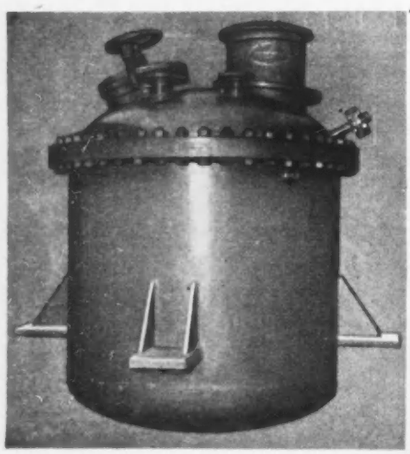
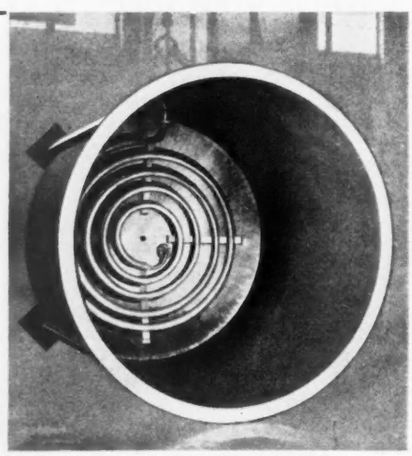


CHEMICAL
PLANT
& EQUIPMENT

COPPER
ALUMINIUM
STAINLESS STEEL
MILD STEEL



PLANT to Specification

CONDENSERS
DISTILLATION UNITS
REACTORS Etc.

PRESSURE VESSELS
OF ALL KINDS

DELIVERIES PROMPT
PRICES COMPETITIVE

CRAFTSMANSHIP IN
ALL METALS

J. A. WELCH (PLANT & VESSEL) LTD.

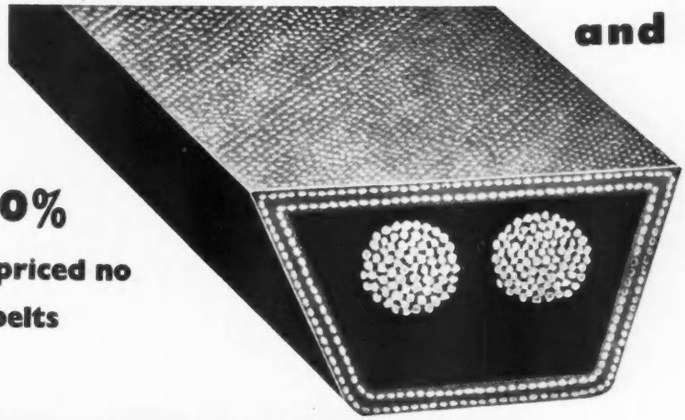
STALCO WORKS, LIVINGSTONE RD., LONDON, E.15

TELEPHONE : MARYLAND 5818 (3 lines).

Enter No. 1302 on reply card

There's a *Big Difference*

between this



and any other V-belt

LAST 20 to 50% LONGER... Yet priced no higher than ordinary belts

TEXROPE Grommet V-Belts

ALL BRITISH *TEXROPE* GROMMET V-BELT DRIVES MANUFACTURED AND SOLD ONLY BY

FRANK WIGGLESWORTH & CO LTD

SHIPLEY YORKSHIRE

'Phone : SHIPLEY 5314†
Grams : CLUTCH, SHIPLEY

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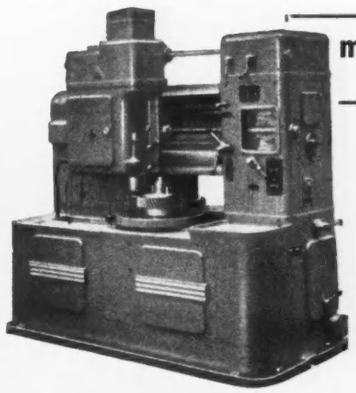
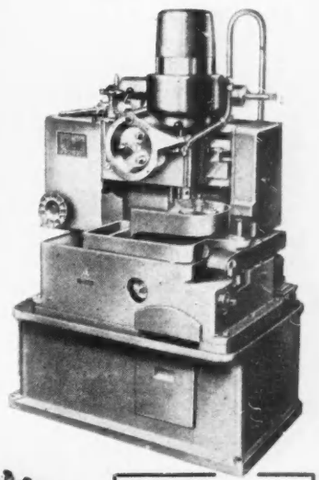
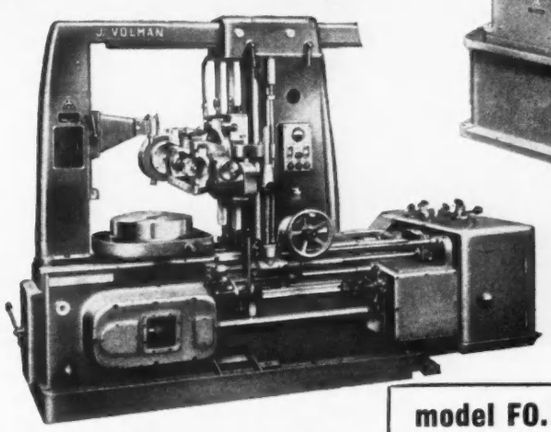
VOLMAN
GEAR HOBBERS & GEAR SHAPERS



model OH. 6
Capacity external gears 17½"; internal gears 19½" x 6 mod.





model OH. 4
Gear Shaper, Capacity 7½" x 6 D.P.

Unequalled for rapid, precision production of all types of gears—backed by over 35 years' experience.

UNEQUALLED VALUE

Immediate Delivery

ALSO AVAILABLE MODEL FO.10 CAP. 49" dia. x 10 MOD.

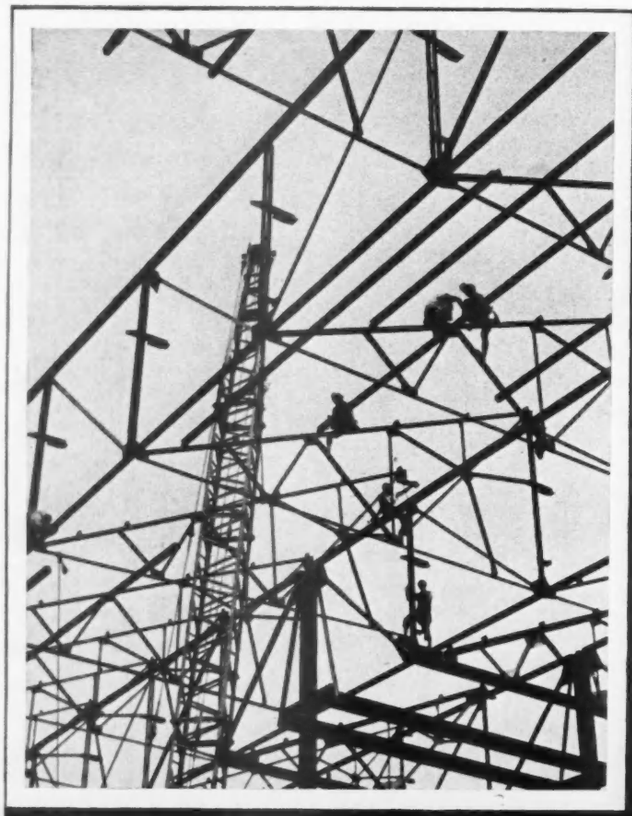
model FO. 6
Capacity 31½" diameter 4 x D.P. Tangential Head available for cutting worm wheels.

EXCLUSIVE DISTRIBUTORS IN THE UNITED KINGDOM

ELGAR MACHINE TOOL COMPANY LIMITED

172-178 VICTORIA ROAD · ACTON · LONDON W3 · Telephone ACORN 5555 MIDLAND SHOWROOMS · 1075 KINGSBURY ROAD · BIRMINGHAM 24

Enter No. 1312 on reply card



LOCATION—
Durgapur—India

In course of erection is shown the lattice girders and roof trusses to the Light and Heavy Machine Shops and Loco Repair Shops for the Central Engineering Maintenance Department of the Durgapur Steel Project.
These form part of one of the several buildings of which the steelwork has been designed, fabricated and erected by CLEVELAND.

Construction by **CLEVELAND**

THE CLEVELAND BRIDGE & ENGINEERING CO. LTD. DARLINGTON, ENGLAND.

Enter No. 1321 on reply card

CLASSIFIED ADVERTISEMENTS

AGENCIES · DIRECTORS · PARTNERSHIPS · SITUATIONS VACANT · EDUCATIONAL PATENTS · BUSINESS OPPORTUNITIES · MISCELLANEOUS · PUBLIC APPOINTMENTS BUSINESSES and PREMISES · TENDERS

Lineage Rate. 4/- per line of approximately 6 words. Minimum 16/-.

Inch Rate. 48/- per single column inch and pro rata. 12 lines to 1 inch. There are reduced rates (i.e., not on a pro rata basis) for advertisements of ¼-page (12 column inches) and upwards, e.g., ¼-page £25 10s. ½-page £48. Full page £90

AUCTION SALES · FOR HIRE · MACHINERY, etc., WANTED · SITUATIONS WANTED DRAWING AND DESIGN SERVICES · FOR SALE · SUB-CONTRACTING

Lineage Rate. 3/6 per line of approximately 6 words. Minimum 14/-.

Inch Rate. 42/- per single column inch and pro rata. 12 lines to 1 inch. There are reduced rates (i.e., not on a pro rata basis) for advertisements of ¼-page (12 column inches) and upwards, e.g., ¼-page £22. ½-page £41 10s. Full page £78.

Series Discounts. For advertisements 1 inch and upwards. 6 insertions 5%. 13 insertions 10%. 26 insertions 15%.

Run-On and Semi-Displayed Styles. Both these styles are available for single column width advertisements of any depth up to 12 inches.

Displayed and Illustrated Styles. The minimum size for a Displayed advertisement is 3 inches single column, for an illustrated advertisement it is a ¼-page (12 column inches). Thereafter the sizes for both progress in steps 3 inches deep across 1, 2, 3 or 4 columns.

Use of Box Number. 2/- which includes forwarding of replies.

Copy Dates. "Run-on" and "Semi-displayed" advertisements by noon Tuesday for publication on Friday same week. "Displayed" and "Illustrated" advertisements by noon Friday for publication on following Friday. All advertisements three days earlier if proofs are required.

Advertisements for publication should be addressed to:—**Classified Advertisement Dept., "The Engineer", 28 Essex Street, Strand, London, W.C.2.**

Urgent advertisements may be telephoned to CENtral 6565

PUBLIC APPOINTMENTS

UNIVERSITY OF CAPE TOWN

TECHNICAL ASSISTANT: CIVIL ENGINEERING

There is a vacancy for a I Grade TECHNICAL ASSISTANT in the Department of Civil Engineering. The successful applicant should have workshop experience, preferably including work in a research laboratory and on maintenance of instruments and electrical and hydraulic machinery. The post is vacant from 1st January, 1960.

The salary scale is £1080 by £60 to £1260 per annum.

Applications (with copies of testimonials) should state age, experience and qualifications, and give the names of two referees whom the University may consult. Two copies of the application and testimonials should reach the Secretary, Association of Universities of the British Commonwealth, 36, Gordon Square, London, W.C.1 (from whom a memorandum giving the general conditions of appointment should be obtained) not later than 17th November, 1959. An additional copy should be sent direct by air mail to the Registrar, University of Cape Town, Private Bag, Rondebosch, Cape Town, South Africa, by the same date.

The University reserves the right to appoint a person other than one of the applicants or else to make no appointment. E7660

UNIVERSITY COLLEGE OF SWANSEA

ASSISTANT LECTURESHIP OR LECTURESHIP IN MECHANICAL ENGINEERING

Applications are invited for a LECTURER IN MECHANICAL ENGINEERING, in the Department of Engineering. In the past three years the Department has considerably expanded its facilities for both teaching and research, and a further major expansion is due shortly. The Selection Committee will be particularly concerned with the potential achievement as well as the present qualifications of applicants. The person appointed will be expected to carry out research for which facilities will be provided. The appointment can be either an Assistant Lectureship (£700 to £850) or a Lectureship (£900 to £1650) which also carry membership of the F.S.S.U. and children's allowances.

Further particulars may be obtained from the Registrar, University College, Singleton Park, Swansea, by whom six copies of applications must be received by Saturday, 7th November, 1959. E7613

UNIVERSITY OF LEEDS

DEPARTMENT OF ELECTRICAL ENGINEERING

LECTURER

Applications are invited for appointment as LECTURER in the Department of Electrical Engineering, from January 1st, 1960. Candidates should have good academic qualifications and experience in the field of electric power engineering, preferably electrical machines. Salary will be on the scale £900 by £50 to £1350 (efficiency bar) by £75 to £1650 a year. Applications (three copies), stating date of birth, qualifications and experience, together with the names of three referees, should reach the Registrar, The University, Leeds, 2 (from whom further particulars may be obtained) not later than 20th November, 1959. E7638

KENT EDUCATION COMMITTEE

NORTH-WEST KENT COLLEGE OF TECHNOLOGY

MECHANICAL ENGINEERING DEPARTMENT

ASSISTANT (GRADE B)

ASSISTANT (GRADE B) required to teach Mathematics up to National Certificate standard. Ability to teach English or Science an additional recommendation. Salary: £700 by £27 10s. to £1150 p.a. Forms of application are obtainable from the Principal of the College, Miskin Road, Dartford, to whom they should be returned as soon as possible. E7637

CITY OF LIVERPOOL EDUCATION COMMITTEE

COLLEGE OF TECHNOLOGY

Principal: S. A. J. PARSONS, B.Sc. (Econ.), M.I.Mech.E., M.I.Prod.E., M.B.I.M.

DEPARTMENT OF MARINE ENGINEERING

Applications are invited for the appointment of ASSISTANT, Grade "B," to teach Marine Engineering Subjects. (Duties to commence 1st January, 1960.)

Salary, Men: £700 by £27 10s. to £1150 per annum (Burnham Technical Report). To this scale additional graduate and training allowances, where applicable, will be paid. Increments up to a maximum of twelve may be allowed for professional or war service.

Applicants should possess a First Class M.T.C.A. Certificate of Competency as a Marine Engineer and, preferably, also a Higher National Certificate in Mechanical Engineering or its equivalent.

The work of the Department of Marine Engineering consists of preparing seagoing engineers for the Second, First and Extra First Class Examinations for M.T.C.A. Certificates of Competency.

Further particulars and application form (returnable by 7th November, 1959) from H. S. Magnay, M.A., Director of Education, 14, Sir Thomas Street, Liverpool, 1.

THOMAS ALKER,
Town Clerk and Clerk to the Local Education Authority

(J.5884) E7688

MIDDLESEX COUNTY COUNCIL EDUCATION COMMITTEE

WILLESDEN TECHNICAL COLLEGE, DENZIL ROAD, WILLESDEN, N.W.10

Required for 1st January, 1960:

ASSISTANT, Grade "B," for Practical Machine Shop Classes. Good knowledge of machine tools essential.

ASSISTANT, Grade "B," to teach Refrigeration subjects.

Salary within the range £738–£1201 per annum for non-graduates.

Application forms (foolscap s.a.e.) from the Clerk to the Governing Body, 163, Willesden Lane, N.W.6. Closing date 2nd November, 1959.

C. E. GURR, M.Sc., Ph.D.,
Secretary to the Education Committee.

E7673

CITY OF BIRMINGHAM WATER DEPARTMENT

ASSISTANT ENGINEERS

Applications invited from Chartered Civil Engineers for above appointments. Salary within: (a) Grade A.P.T. IV., £1065–£1220 per annum (considerable water engineering experience essential), and (b) Special Grade for Engineering Assistants, £785–£1070 per annum (water engineering experience desirable). The Engineer appointed to (a) would be engaged upon development of new source of supply, and (b) on new water supply works in or near Birmingham. Appointments permanent and pensionable—medical examination. Canvassing disqualifies.

Application forms from General Manager, Water Department, Council House, Birmingham, 3, returnable by 9th November, 1959. E7696

CITY OF PORTSMOUTH

HEATING AND VENTILATING ENGINEERS

Vacancies for HEATING AND VENTILATING ENGINEERS.

(a) One Grade A.P.T. IV (£1065–£1220 per annum).

(b) One Grade A.P.T. I/II (£610–£880 per annum)—commencing salary according to experience and qualifications.

Further particulars can be obtained from City Engineer, 1, Clarence Parade, Portsmouth, to whom applications should be delivered not later than Saturday, 14th November, 1959. E7691

FEDERAL GOVERNMENT OF NIGERIA

SENIOR ELECTRICAL INSPECTOR

To investigate and conduct enquiries into electrical accidents; inspect electrical undertakings and installations at mines, oil wells, factories, &c., and examine electricians and craftsmen for the issuing of certificates of competence.

Contract appointment. Salary range £1728–£1962. Gratuity of £37 10s. for each three months' satisfactory service. Quarters at moderate rent. Free passages. Allowance for children maintained in U.K. Generous home leave.

Candidates not over 45 years must be A.M.I.E.E., with at least ten years' post qualifying experience of responsibility with an electrical supply undertaking or as an electrical engineer with a large industrial establishment.

Write Director of Recruitment, Colonial Office, London, S.W.1, stating full names, age, qualifications and experience, quoting BCD 99/14/013/D4.

E7653

GOVERNMENT OF BRITISH GUIANA

PUBLIC WORKS DEPARTMENT

MECHANICAL ENGINEER

To maintain all Public Works Department equipment, including road-making equipment and sea and river defence machinery.

Contract appointment. Salary in the range £1100–£1400 per annum. Gratuity 22½ per cent. of salary. Free passages.

Candidates must be A.M.I.Mech.E. or Grad. I.Mech.E., or exempt from Parts I and II of the Institution's examination with at least five years' relevant experience.

Write: Director of Recruitment, Colonial Office, London, S.W.1, giving full names, age, qualifications and experience, quoting BCD 112/30/011/D4.

E7667

CIVIL SERVICE COMMISSION

RESEARCH FELLOWSHIPS

RESEARCH FELLOWSHIPS (3 years) in Government Scientific Establishments. Value £1150–£1400 (Senior) and £800–£1100 (Junior). Very wide range of topics, especially in the physical sciences, organic chemistry, including solution thermodynamics of high polymers, irradiation of polymer solutions, meteorology, metallurgy, forensic science. A few opportunities for biologists, e.g. in virology, taxonomy and physiology as applied to fisheries, veterinary research, and oyster catcher control. Qualifications: normally first or second class honours degree; evidence of high standard of ability in research; and at least 2 years' post-graduate research experience (3 years for Senior Fellowships). No age limits. F.S.S.U. Write Civil Service Commission, 17, North Audley Street, London, W.1, for application form, quoting S4932/59.

E7652

BUCKS WATER BOARD

ASSISTANT ENGINEER

Applications are invited from suitably qualified engineers for the above appointment on Grade A.P.T. IV (£1065 to £1220) of the National Joint Council for Local Authorities, to assist with the design and preparation of contract documents and to supervise the construction of that part of a large development scheme consisting of a reinforced concrete reservoir, mains, pumping stations, &c., which is being carried out to my instructions. The appointment is permanent and superannuable; a car allowance will be given on the Board's essential users scale.

Applicants should apply to the following address not later than 6th November, 1959, giving details of their qualifications and experience and submitting the names of two persons to whom reference may be made.

R. POWNALL,
Engineer and Manager.

Byron Road,
Aylesbury. E7681

FIGHTING VEHICLES RESEARCH AND DEVELOPMENT ESTABLISHMENT

CHERTSEY

PHYSICIST OR MECHANICAL ENGINEER

PHYSICIST or MECHANICAL ENGINEER required at Fighting Vehicles Research and Development Establishment, Ministry of Supply, Chertsey, Surrey, for theoretical, laboratory and field investigations into wide range of research problems connected with unorthodox forms of future fighting vehicles, with particular emphasis on aspects concerning nuclear warfare. Considerable scope for research in new problems of A.F.V. design. Appointment in Grade: (a) Senior Scientific Officer (minimum age 27 and at least 3 years' post graduate research experience), or (b) Scientific Officer. 1st or 2nd Class Hons. Degree in Physics or Engineering or equivalent qualifications required for both grades. Some knowledge of nuclear physics essential.

Salary ranges: (a) £1166–£1380; (b) £615–£1090. Superannuation under F.S.S.U. Opportunities for those under 31 to compete for established (pensionable) posts.

Forms from M.L.N.S., Technical and Scientific Register (K), 26, King Street, London, S.W.1, quoting A.461/9A. E7666

SOUTH WEST METROPOLITAN REGIONAL HOSPITAL BOARD

REGIONAL ENGINEER'S DEPARTMENT

SENIOR ASSISTANT ENGINEERS

Applications are invited for the following appointments on the permanent staff of the Board, generally in accordance with the Whitley Council conditions of service.

SENIOR ASSISTANT ENGINEERS (MECHANICAL) AND (HEATING AND VENTILATING):

The commencing salary will be at the minimum of the scale £1050 by £30 (3) by £35 (3) to £1245 per annum, plus London Weighting allowance of £50 per annum (scale under review). Applicants should be Corporate Members of the Institution of Mechanical Engineers and should be experienced in the preparation of specifications, drawings and estimates for large engineering installations in hospitals and large public buildings.

Applications, stating age, qualifications, experience, present appointment and salary, together with the names and addresses of three referees, should be sent to the undersigned at 40, Eastbourne Terrace, London, W.2, by not later than 3rd November, 1959.

E. G. BRAITHWAITE,
E7692 Secretary.

COQUET WATER BOARD

APPOINTMENT OF ASSISTANT RESIDENT ENGINEER

Applications are invited for the position of ASSISTANT RESIDENT ENGINEER to be employed for a period of about 18 months at Warkworth, Northumberland, on the construction of the Board's filtration works and pumping station. These Works, which are estimated to cost about £250,000, include for the laying of 36in. steel pipelines, sheet piling, deep excavation and reinforced concrete construction.

The successful applicant will be required generally to assist the Resident Engineer and to take control of the Works in his absence.

The salary offered will depend upon the experience and age of the successful applicant but will not exceed £1200 per annum.

Forms of application may be obtained from Mr. S. G. Barrett, Engineer and Manager to the Coquet Water Board, P.O. Box 104, Pilgrim Street, Newcastle upon Tyne, and should be returned as directed not later than the 16th November, 1959.

F. G. EGNER,
Clerk and Solicitor to the Board.
14, Northumberland Square,
North Shields. E7650

Classified Advts. continued on page 134

PUBLIC APPOINTMENTS

RESIDENT ENGINEER—GHANA

Applications are invited from suitably qualified persons in Mechanical/Electrical Engineering for the post of Resident Engineer with a Gold Mining group in Ghana.

The Resident Engineer is directly responsible to the General Manager for the construction and maintenance of the plant and machinery on the Mine and must have the ability to organise and control a large Engineering staff.

Salary in the range of £2500–£3000, dependent on the qualifications and/or experience of the successful candidate.

The post is permanent and pensionable. Tours abroad of 15 months followed by 3 months' leave on full pay, with free passages. Income-tax at low local rates. Marriage allowance of £180 per year or free passages for wife each tour. A car is provided for use on the property. Good housing and basic furniture provided free. Excellent sporting facilities in pleasant surroundings.

Applications in confidence to BOX No. E7684, "The Engineer."

HEREFORDSHIRE WATER BOARD

APPOINTMENTS

Applications are invited for the whole time posts of :

(a) CLERK AND TREASURER ; and

(b) ENGINEER AND MANAGER

to the recently established Herefordshire Water Board covering the whole of the County of Hereford (except the Parishes of Colwall and Mathon Rural).

The salary scale for Post (a) will be £1520 p.a. by £60 (3) by £55 (1) to £1755 ; and for Post (b) £2200 p.a. by £85 (3) by £75 (1) to £2530.

Travelling allowances will be payable on Essential Users scale.

The appointments are superannuable and the successful applicants will be required to pass medical examinations.

Applications must be received by the Clerk of the Herefordshire County Council, Shirehall, Hereford, before 12 noon on Friday, 13th November, 1959, on a form to be obtained from him. E7644

TENDERS

MINISTRY OF TRANSPORT AND CIVIL AVIATION

THE DARTFORD TUNNEL

ESSEX APPROACH ROAD—EXCAVATION AND SERVICE CULVERTS

The Minister of Transport and Civil Aviation invites TENDERS for the following WORKS in connection with the Essex Approach to the above tunnel.

(1) About 400,000 cubic yards of EXCAVATION in chalk and overburden. Some 300,000 cubic yards of chalk is to be delivered to quarries adjacent to the site, and the remaining excavated material is to be disposed of as filling or in tips on and off the site.

(2) The CONSTRUCTION of TWO SERVICE CULVERTS in reinforced concrete, about 22 yards and 25 yards long respectively, and 7ft. 9in. high by 5ft. wide internally.

(3) FENCING, DRAINAGE, TEMPORARY ACCESS ROUTES and other ancillary works.

Copies of the contract documents may be obtained from the Consulting Engineers, Messrs. Mott, Hay and Anderson, 9, Iddesleigh House, Caxton Street, Westminster, London, S.W.1, on payment of a deposit of £10 by cheque, made payable to the Minister of Transport and Civil Aviation. The deposit will be returned if a bona fide Tender is submitted and not subsequently withdrawn.

Tenders should be sent by registered post in envelopes endorsed "Tender for Essex Approach Excavation, &c.," but not having any name or marking indicating sender, addressed to the Assistant Secretary, Highways Management and Services Department, Ministry of Transport and Civil Aviation, 21–37, Hereford Road, London, W.2, to arrive not later than 4 p.m., Tuesday, the 24th November, 1959.

The Minister does not bind himself to accept the lowest or any Tender.

H. GILLENDER,
An Assistant Secretary.

E7663

INDIA SUPPLY MISSION

WASHINGTON, D.C.

The India Supply Mission, Washington, D.C., invites TENDERS for the SUPPLY of :—

Sl. No.	Description of Equipment	Enquiry No.	Closing Date	Price, P/Tender
1	CENTRIFUGAL PUMPS	SE-73	3rd Dec., 1959	21/6d.
2	HEAVY DUTY AGITATORS	SE-76	8th Dec., 1959	21/6d.
3	STEAM JET SYPHONS	SE-96	10th Dec., 1959	14/2d.
4	MIXING EDUCTORS	SE-97	10th Dec., 1959	14/2d.
5	CONTINUOUS WATER HEATERS	SE-99	10th Dec., 1959	14/2d.

Forms of Tender may be obtained from the India Store Department (CDN Branch), Government Building, Bromyard Avenue, Acton, London, W.3, upon a payment of a fee as stated above, which is not returnable. The relevant Enquiry No. and Reference No. S.3634/59 (CDN), must be quoted in all applications. E7672

TENDERS

MINISTRY OF TRANSPORT AND CIVIL AVIATION

RECONSTRUCTION OF OVERLINE BRIDGE G.C.337 ON TRUNK ROAD A.6 AT LOUGHBOROUGH, LEICS.

The Minister of Transport and Civil Aviation invites TENDERS for the RECONSTRUCTION of the above BRIDGE, consisting of a single 70ft. skew steel span 40ft. wide between parapets.

Tender documents may be obtained from the Consulting Engineer, A. M. Hamilton, M.I.C.E., M.Cons.E., 17, Dartmouth Street, S.W.1. (Tel.: Abbey 6336), on payment of a deposit of £10 (ten pounds) by cheque or draft, payable to the order of the Minister of Transport and Civil Aviation. The deposit will be returned if a bona fide Tender is submitted and not subsequently withdrawn. Prospective Tenderers may inspect contract documents and drawings at the offices of the Consulting Engineer before payment of the deposit.

Tenders on the official form should be sent by registered post (in the printed envelope supplied) to the Assistant Secretary, Highways Management and Services Division, Ministry of Transport and Civil Aviation, 21/37, Hereford Road, London, W.2, and will only be considered if received not later than 4 p.m. on 24th November, 1959.

The Minister does not bind himself to accept the lowest or any Tender.

H. GILLENDER,
An Assistant Secretary.

E7664

COUNTY BOROUGH OF BIRKENHEAD

WATER DEPARTMENT

FIXED PRICE TENDERS

Fixed Price TENDERS are invited for the SUPPLY, DELIVERY, ERECTION and MAINTENANCE of a 30kW., 245 volts D.C. WATER TURBINE GENERATING UNIT. The Unit is to incorporate an electric brake governor to allow variation of the useful electrical load whilst a constant flow of compensation water is passing through the Turbine. Conditions of contract, form of Tender, specification, bill of quantities and drawings may be inspected at the Water Engineer's Office, 601, Borough Road, Birkenhead, Cheshire, and supplied on deposit of £2 2s., returnable on receipt of a bona fide Tender.

Closing date for Tenders, Wednesday, 25th November, 1959.

E7690

MADRAS PORT TRUST

The Office of the Chief Engineer, Madras Port Trust, Madras, India, invites TENDERS for the following :—

(a) TENDER ENQUIRY No. A/186/59/EP. For the SUPPLY of 77 Nos. CAST STEEL BOLLARDS.

(b) TENDER ENQUIRY No. D/25336/59/EP. For the SUPPLY of 2 Nos. 10-Ton WHARF CRANES for General Cargo Handling.

Specifications, drawings, &c., relative to the above can be obtained direct from the Deputy Chief Accounts Officer (Engineering), Chief Engineer's Office, Madras Port Trust, Madras, India, on payment of : (a) 7 shillings and sixpence per set, and (b) £1 10s. per set, and is not refundable. Tenders are to be returned direct to the Chief Engineer's Office (at "C" Warehouse), Madras Port Trust, Madras, India, so as to reach them by 2.30 p.m. on 24th November, 1959, for (a) and 4th December, 1959, for (b).

Specimen copy of the above specification can be seen at "India Store Department," Engineering Branch, Government Building, Bromyard Avenue, Acton, London, W.3, under reference S.3629/59/NSC/ENG.2 for (a) and S.3636/59/NSC/ENG.2 for (b). E7662

EDUCATIONAL

A.M.I.MECH.E., B.Sc., City and Guilds, &c. Guarantee Postal Courses for all Exams. and Technical Divisions from Elementary to Degree standard including Automation Techniques. Approximately 95 per cent. successes. 148-page prospectus free on request.—B.I.E.T. (Dept. 22), 29, Wright's Lane, London, W.8. E114 E

SITUATIONS VACANT

APPLICANTS ARE ADVISED TO SEND COPIES NOT ORIGINALS OF THEIR TESTIMONIALS UNLESS OTHERWISE REQUESTED.

A YOUNG ENGINEER required for Specialised Products Dept. Applicants should have the following qualifications : (a) age up to 24 years ; (b) Post Graduate or equivalent education qualifications ; (c) Knowledge of Pneumatic Equipment.—Apply in writing, stating experience, also salary required to The Technical Director, Wellworthy, Ltd., Lymington, Hants. E7640 A

APPLICATIONS are invited from ENGINEERS for responsible posts on research and development of PRODUCTION PROCESSES for the engineering industry. Excellent opportunities for those with ability and initiative. Candidates should have an engineering degree, Higher National Certificate, or equivalent qualification. Excellent working conditions in pleasant surroundings. Superannuation scheme. Removal expenses paid.—Send full details including age, qualifications, experience and present salary in confidence to BOX No. E7655, "The Engineer." A

ASSISTANT CHIEF DRAUGHTSMAN required by expanding Company in Surrey approximately 25 minutes from Waterloo. Successful applicant should be experienced in the design of small mechanisms, &c., be a good disciplinarian, and in view of the specialised nature of the product will be expected to make his career with the Company. Minimum qualification of H.N.C., but men with experience and a sound background who are not so qualified will be considered.—BOX No. E169, "The Engineer." A

ASSISTANT WORKS SUPERINTENDENT

now required by large Industrial Group at Factories situated in Northern England.

The immediate position envisaged is one of understudy to present Superintendent.

The position, which is superannuable, holds future scope for man of ability, with experience of plant maintenance and upkeep, coupled with ability to control staff.

Commencing salary will be not less than £1500 per year.

Applications, which will be treated in strict confidence, are invited from candidates age 30 to 38. Send full particulars of education, age, experience, and present earnings, &c., to BOX No. E7595, "The Engineer." A

CONSULTING CIVIL ENGINEERS, Westminster, require a fully qualified STRUCTURAL ENGINEER with wide experience, for position as CHIEF DESIGNER in reinforced and prestressed concrete and structural steelwork (including bridges). Prospects of partnership interest in firm. Write in confidence, stating age and full details of experience and qualifications.—BOX No. E2594, "The Engineer." A

CRAVENS, LTD., SHEFFIELD, require DRAUGHTSMEN with experience in General Engineering, Rolling Stock or Machine Tool Design. Minimum qualification O.N.C. Pension Scheme, &c.—Apply Personnel Manager. E7641 A

DESIGN ENGINEER required by firm of Hydraulic and Heavy Mechanical Engineers. Canteen facilities and Superannuation Scheme.—Write, giving details of age, experience and salary required to Chief Engineer, Henry Berry and Co., Ltd., Croydon Works, Leeds, 10. E2584 A

DESIGNER-DRAUGHTSMEN

An Engineering firm of repute in the Eastern Counties has vacancies for two experienced DESIGNER-DRAUGHTSMEN, aged 25–36. Minimum qualification H.N.C. or equivalent, one appointment being for a Graduate or Associate Member Inst.Mech.E., to assume responsible position after period of training.

Candidates must prove ability to produce sound designs and to accept responsibility for mechanical and structural projects of unusual as well as orthodox nature. Experience of crane type structures and/or medium heavy contractor's plant an advantage.

Attractive salaries to suitable applicants. There is a contributory pension scheme and good canteen facilities.

Write in confidence giving full information about qualifications, experience and salary required quoting Ref. No. K.5974 to :

WRIGHT ATKINSON, LTD.,
Employment Consultants,
70, Queen Victoria Street,
London, E.C.4.

E7694 A

DRAUGHTSMAN MECHANICAL (SENIOR) required by the British Drug Houses, Ltd., for layout and special machine development in their chemical laboratories. H.N.C. or equivalent preferred. Five-day week, canteen, sports club, pension and profit-sharing schemes.—Apply in writing, stating age and educational attainments, to the Staff Manager, Graham Street, City Road, N.1. E7626 A

DRAUGHTSMAN required for designing and detailing structures and mechanical handling equipment, including conveyors. Cheltenham area. Good salary and conditions. Write, giving full details of experience and qualifications.—BOX No. E2593, "The Engineer." A

DRAUGHTSMAN.—An experienced Draughtsman required, with a good knowledge of A.C. and D.C. circuits, by a modern and progressive company. Candidates should have O.N.C. Electrical Engineering. Salary will be in accordance with age and experience. The position is permanent with a contributory pension plan. Applications will be treated in strict confidence. Please apply, giving full details. —BOX No. E2591, "The Engineer." A

SITUATIONS VACANT

ENGINEER, with several years' operational experience in Petroleum or Tar Distillation plants to act as Assistant to Refinery Manager in North Kent area.—Details of experience, qualifications and salary expected to BOX No. E2586, "The Engineer."

ENGINEER.—The British Drug Houses, Ltd., require a young Graduate in Mechanical Engineering, preferably with some chemical experience, for experimental and development work in their laboratories. Five-day week, canteen, sports club, pension and profit-sharing schemes.—Apply in writing, stating age and educational attainments, to the Staff Manager, Graham Street, City Road, N.1. E7627 A

FIRM IN SOUTH COAST AREA, manufacturing components for the motor industry, requires DESIGN DRAUGHTSMEN and JUNIOR DRAUGHTSMEN. Experience of gravity die casting an advantage. Write, stating age, details of experience, qualifications and salary required.—BOX No. E7669, "The Engineer." A

FUEL EFFICIENCY ENGINEER required by National Coal Board in Scottish Division. The successful candidate will be located in Edinburgh but will be required to visit colliery boiler installations throughout the Division. Salary, according to qualifications and experience, within the range £750 to £1150 per annum. Applicants should have general mechanical engineering training, with experience on industrial steam plant (shell boilers, mechanically and hand-fired). Possession of recognised technical qualifications advantageous.—Applications, stating age, education, qualifications, experience, present post and salary, to Staff Department, National Coal Board, 3, Eglinton Crescent, Edinburgh, 12. E7661 A

GENERAL MANAGER required by Structural Engineers and Bridge Builders with a fabricating department, in the Dudley/Wolverhampton area. Must have had previous experience with Lloyds Class I approved company for welded vessels, and first-class knowledge of welding procedure. Required to take charge of works and general administration and development of heavy welded fabrications. Apply, stating age and experience. Applications will be treated in the strictest confidence.—BOX No. E2590, "The Engineer." A

GOOD YOUNG FOREMAN ELECTRICIAN preferably single, required for West Africa. Able to supervise installation contracts and control labour. Good terms, conditions and prospects. Apply, stating age, qualifications, pay required, &c.—BOX No. E2592, "The Engineer." A

MATERIALS ENGINEERS

A new division of the Development and Research Department of The Mond Nickel Company, Ltd., London, has been formed to promote the application of nickel-containing materials in modern engineering practice. Applications are invited from progressive engineers having a degree or equivalent qualification, experience in engineering and a working knowledge of metallurgy. Metallurgists with practical engineering experience would also be considered. Pension and assurance schemes are in operation and, in appropriate cases, assistance can be given with housing.

Applicants should write to the Secretary, Development and Research Department, The Mond Nickel Company, Ltd., Thames House, Millbank, London, S.W.1, stating age, experience and salary expected. Mark envelope "Confidential Dev. 29."

E7636 A

MONSANTO CHEMICALS LIMITED

require the following Engineers for their Ruabon Works (North Wales).

(1) A MECHANICAL ENGINEER for development schemes connected with Factory Utilities. Applicants should be of A.M.I. Mech.E. standard and have had some experience in this field. The successful applicant would be a specialist within the Technical Services Department and responsible for the development of steam, water and compressed air facilities throughout the factory. He would also be required to work in collaboration with an Electrical Engineer towards providing an economic steam and power balance throughout the factory.

(2) A WORK STUDY ENGINEER to advise on the use and application of Method Study techniques and Cost Control methods as applied to Maintenance Engineering operations. He would be required to direct investigations in person and also organise Method Study training. Applications are invited from men between the ages of 28 and 40, having a good Industrial Engineering background and a high degree of practical judgment and initiative. Some experience in Ratio Delay studies is desirable.

(3) MECHANICAL ENGINEERS. Applicants should possess a University Degree or equivalent qualification, with preferably 2–3 years' Industrial Engineering experience. The men appointed will be required to assist in investigational work involving Maintenance Engineering operations and to liaise effectively with Production and Maintenance supervision. Please send written applications, giving details of training, qualifications and experience, to DL. 108, Personnel Department, Monsanto Chemicals, Ltd., Monsanto House, 10/18, Victoria Street, London, S.W.1. E7665 A

MECHANICAL ENGINEER with senior status required for research and development work in Manchester. Honours Degree, good knowledge of thermodynamics metallurgy and experience with design calculations of various kinds of thermal plant essential.—Apply, Kennedy and Donkin, 12, Caxton Street, London, S.W.1, or 64, Royal Exchange, Manchester. E7677 A

SITUATIONS VACANT

MECHANICAL ENGINEER, required for Works in North Kent. With good experience in maintenance of steam, reciprocating and electrical pumps, &c., piping, boilers and general plant. Knowledge of maintenance of heavy road transport and rail tanks desirable.—Details of experience, qualifications and salary expected to BOX No. E2585, "The Engineer." A

NIGERIAN ENGINEERING SUPERVISOR required for care and maintenance of Palm Oil Bulking Installation in West Africa. Qualifications not less than O.N.C. in Mechanical Engineering and preferably H.N.C. Practical knowledge of Boiler Plants, Steam and I.C. Engines, Centrifuges and Electrical Installation an advantage. Advertiser anticipates required experience will not have been achieved by anyone under 28. Salary dependent on qualifications and experience but not less than £650 per annum. The position is permanent and pensionable. Please apply.—BOX No. E7682, "The Engineer." A

SENIOR DESIGN ENGINEER, H.N.C. preferred, knowledge of hydraulics desirable and capable of designing, on own initiative, medium heavy machinery.—Apply Mr. Bedford, Chamberlain Industries, Ltd., Staffa Road, Leyton, E.10 (Tel.: LEY 3678). E7623 A

PILKINGTON BROTHERS, LTD. have a vacancy in their City Road Works drawing office for a DRAUGHTSMAN to work on the design of special purpose machinery for the edgeworking of glass and the improvement of major plant used in glass processing. Previous experience in the design of special purpose machinery is essential and the knowledge of plant layout and foundation work an added advantage. Qualifications: H.N.C. desired, O.N.C. minimum.—Applicants should write giving details of age and experience to the Work Personnel Officer, Cowley Hill and City Road Works, St. Helens, Lancashire. E7643 A

SENIOR DRAUGHTSMAN required for drawing-office section engaged on the application of small diesel engines to marine propulsion. Experience on this type of work is essential and technical qualifications an advantage. This will be a secure and well-paid position with excellent conditions of service.—Apply in writing giving full details to the Personnel Manager, Petters Ltd., Staines, Middlesex. E7685 A

SENIOR DRAUGHTSMEN required for our new offices in Bromley, experienced in the design and/or detailing of bulk material handling plant and steel structures associated with this type of plant.—Reply in writing to John Wilson and Co. (Engrs.), Ltd., 30, Widmore Road, Bromley, Kent. E2589 A

SALES ENGINEER.—A first-class opportunity is offered by an old-established firm located in London, specialising in up-to-date methods and equipment for bulk handling and batching of material for large installations. Applicants should have an engineering background—both mechanical and structural—and possess initiative and drive for introducing and discussing design schemes to prospective customers. The position is pensionable and offers good permanent prospects. Initial salary will be based on age and experience.—Applicants should write, giving age, details of experience and salary required, to BOX TE.325, c/o 191, Gresham House, E.C.2. E7670 A

SENIOR MANAGER.—A Steelworks in the Midlands, with expanding trade in section semis and rounds, wishes to engage a Senior Manager to supervise their finishing and despatch departments. Applicants should be technically qualified and have a working knowledge of modern industrial engineering techniques. Preference will be given to men with experience of roller straightening and ancillary processes. The post is a progressive one and there is a pension scheme and free life assurance scheme in operation. Applications, with full details of age, qualifications and experience.—BOX No. E7679, "The Engineer." A

WANTED, young competent ENGINEER with experience of plant layout. Good prospects for suitable applicant. Apply stating age, experience and qualifications which must include Higher National Certificate or equivalent.—BOX No. E2571, "The Engineer." A

WANTED, FIRST-CLASS SENIOR DESIGN DRAUGHTSMAN for firm of General Engineers in Bristol. Good knowledge of general engineering, with particular reference to pressure vessels and stainless steel fabrication. This will be a well-paid position for the top-class man.—BOX No. E164, "The Engineer." A

WATER TREATMENT DRAUGHTSMEN
DRAUGHTSMEN, senior or junior, with experience in water treatment are required by a rapidly expanding firm who can offer permanent pensionable positions, with a profit sharing bonus which last year amounted to 22 per cent. of salary.—Apply, in writing to William Boby and Co., Rickmansworth, Hertfordshire. E7644 A

WELDING SUPERVISOR required in Kent area, with wide experience of Stainless Steel, Copper, &c., to supervise welding of X-ray quality. Applicants should be fully conversant with pressure vessel codes of construction and able to train welders to standard required. Replies will be opened in strict confidence by the Production Engineer. Please give full details of experience and salary required.—BOX No. E7544, "The Engineer." A

WORKS SUPERINTENDENT required for small precision engineering works (A.I.D. and non-repetitive). Practical shop experience and apprenticeship essential. Responsible to Managing Director for output, quality and tool design. Must have leadership and ability to gain confidence. Age not over 35, starting salary of approximately £1000, with opportunities to advance. Works in Bath. Interview probably in London. Give full details of experience, jobs held and salaries.—BOX No. E7687, "The Engineer." A

STRESSMAN

FOR TRACTION ROLLING STOCK

DESIGN OFFICE

A Stressman is required by the Traction Rolling Stock Design Office of the English Electric Company at Preston, Lancs., to carry responsibility to the Chief Designer for the structural analysis of locomotives and rolling stock. This position affords an opportunity for a Stressman with B.Sc., or H.N.C. qualifications and several years' experience in an Aircraft Stress Office, to apply himself to similar work on locomotives. The problems are different from those on Aircraft structures but equally challenging, and they offer scope for new ideas.

Please write, giving full details of experience and qualifications, to Dept. C.P.S., Marconi House, 336/7, Strand, London, W.C.2, quoting reference E1011A.

E7657 A

HAWKER SIDDELEY BRUSH TURBINES LIMITED
GLOUCESTER

have a vacancy for a

TURBINE DESIGN ENGINEER

to occupy a responsible position in Gas Turbine Section. The Company has an extensive programme covering industrial machines in the output range 2500–6000kW.

The successful applicant, who must be well-qualified and have previous turbines experience, will be required initially to cover site commissioning and works test development; he should have a working knowledge of control systems with a flair for practical development.

The Company is interested in employing a first-class man and will offer an appropriate salary. Working conditions are excellent and include participation in a Group Pension Scheme.

Applications, which will be treated in confidence, should contain brief details of personal history and should be addressed to:

The Personnel Officer,
Hawker Siddeley Brush Turbines Limited, Gloucester.

E7654 A

BOOKS and PUBLICATIONS

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Energy Principles in Applied Statics

T. M. CHARLTON, M.A., B.SC., A.M.I.Mech.E. **25s.** *net*

This book rationalizes a difficult branch of engineering theory, and should be of great value to teachers and advanced students.

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Written for students taking Parts I, II and III of the London degree in Mechanical Engineering. The syllabus is sufficiently wide to cover a great many University and Technical College courses.

Prospectuses from: 17 STANHOPE STREET, GLASGOW, C.4

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A monthly journal for the professional electronics engineer.

It circulates to 86 different industries all over the world.

When electronic engineering is studied "Electronic Engineering" is read.

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MECHANICAL AND ELECTRICAL ENGINEERING TECHNICIANS

are required at the Atomic Energy Research Establishment, Harwell, for testing and final adjustment of experimental assemblies being commissioned for use with research reactors: The assemblies include pumps, valves, pressure vessels, flow-meters and control panel instrumentation. Applicants should have served a recognised apprenticeship or have had equivalent training and should preferably have a National Certificate. Experience in light mechanical or light electrical engineering is required.

Salary in the range £725 (at age 26)—£905 p.a. or £905 (at age 30)—£1085 p.a. according to age and experience.

Housing and superannuation schemes.

Please send a POST CARD for details to the Group Recruitment Officer, (5058/25), A.E.R.E., Harwell, Didcot, Berks.

E7659 A

SAFETY OFFICER

required by

THE ATOMIC WEAPONS RESEARCH ESTABLISHMENT, ALDERMASTON, BERKS.

To assist the Officer-in-Charge of the Industrial Safety Section with investigation of special engineering problems associated with accidents and inspection of plant and equipment to Statutory Standards. The duties will also include working with engineering consultants and professional scientific staff investigating special problems associated with safe design and assisting with lecturing and training of personnel in safety matters.

A.M.I.Mech.E., A.M.I.E.E. or equivalent qualification and several years' practical and supervisory experience in workshops, including welding and industrial plant, is required. A good working knowledge of the Factories Acts and relevant Statutory Regulations is essential.

Salary: £1345–£1800.

Contributory Superannuation Scheme. A house or substantial assistance with house purchase will become available for married officers living beyond daily travelling distance.

Postcards for application forms to the Senior Recruitment Officer at A.W.R.E., Aldermaston, Berks. Please quote Ref. 2435/25.

E7639 A

Classified Advts. continued on page 136

SITUATIONS VACANT

THOMAS SMITH & SONS
(RODLEY) LTD.

require experienced

FIRST-CLASS
SENIOR DESIGNER
DRAUGHTSMEN

for development and research work in connection with

EXCAVATORS

5-day week, pension scheme, all social facilities. Please write giving full details of age, experience, qualifications, &c., to

The Secretary,
THOMAS SMITH & SONS (Rodley) LTD.
Rodley, Leeds.

E7635 A

SITUATIONS VACANT

WHESSOE LIMITED
Darlington

require an

ELECTRICAL ENGINEER
(reference 25/59)

in the Erection Division to be responsible for arranging power supply for welding and other equipment on sites. Applicants should be aged 28–35 and have at least Graduate Membership of the I.E.E. Experience of welding machines and transformers will be an advantage. The job involves travelling throughout the country.

Also a

DESIGNER
(reference 26/59)

to work on the design of erection plant equipment and methods. At least H.N.C. required.

Apply in detail to the Staff Officer, Whessoe, Ltd., Darlington, quoting the reference number and mentioning this journal.

E7642 A

SITUATIONS VACANT

THE BLUE CIRCLE GROUP OF CEMENT COMPANIES

CIVIL ENGINEER

Engineers who fulfil the requirements indicated below are invited to apply for a post which, after training, will lead to a senior appointment in the Technical Service Department of the sales organisation of the Group, with excellent prospects of advancement.

The successful candidate is expected to be 30 years of age or less, and must have a good educational background, preferably including a good Degree in Engineering. He must be a Corporate Member of the Institution of Civil Engineers and must have had two or three years' experience of site jobs in reinforced concrete construction, with a Contractor or Consulting Engineer. He must be energetic and have plenty of common sense.

Initial training and experience will be given in the Research Department of the Associated Portland Cement Manufacturers, Ltd. A good salary commensurate with qualifications and experience will be paid. The Group has pension and staff profit sharing bonus schemes and ample facilities for social and sports activities.

Applications, with details of career to date should be addressed to the Director of Research, Associated Portland Cement Manufacturers Limited, Research Department, Greenhithe, Kent. E7649 A

SITUATIONS VACANT

CANADA

DESIGN ENGINEER and DRAUGHTSMEN with recent experience in the design, layout and detailing of mechanical equipment for clarifiers and similar applications for municipal or industrial waste and sewage treatment.

APPLICATION TECHNICIAN (TECHNICAL ASSISTANT) to prepare Company product specifications from Consultant Engineers' specifications and drawings, for quotation purposes, for municipal and industrial sewage and water treatment equipment. O.N.C. desirable.

DESIGN ENGINEER and DRAUGHTSMAN with recent experience in the design, layout and detailing of steel mill equipment, particularly for steel strip, sheet and plate manufacturing and processing. Applicants with similar experience in non-ferrous mill design will also be considered.

This is for a long-term development programme in one of Canada's largest industrial Groups.

Excellent employee benefits. Reply, giving full particulars to :

Dept. C.I.F.,
Canadian Department of Labour,
61, Green Street, London, W.1.

E7634 A

British Titan Products Co Ltd

have vacancies for

MECHANICAL ENGINEERS

at their Grimsby and Billingham Factories.

The Company is primarily concerned with the manufacture of Titanium Dioxide and is characterised by a tenfold expansion in post-war years. This continuing expansion offers plenty of scope for Engineers in the fields of Plant, Maintenance, Construction and Design. The current vacancies are for Maintenance and Construction work with opportunities later in the Design field.

Preference will be given to candidates with a University Degree in Mechanical Engineering, but those with an equivalent professional qualification will also be considered. Post-graduate apprenticeship is essential and the upper age limit for the appointments is 30.

Salaries and prospects are very attractive for men with the right qualifications. Annual bonus scheme and non-contributory endowment assurance and assistance for married men with house purchase and removal expenses.

Applications, in strictest confidence, to be addressed to the

Personnel Manager,
British Titan Products Company, Limited,
Billingham, Co. Durham, quoting reference S.4.

E160 A

CAREERS ABROAD

ASSISTANT MECHANICAL ENGINEER

A leading Gold Mine in Ghana has a vacancy for an Assistant Engineer. Minimum qualifications H.N.C. or equivalent. Some practical experience in mining or allied industry preferable but not essential.

The successful candidate will be responsible to the Chief Engineer for the supervision of plant erection and maintenance.

The post is permanent and pensionable, salary in the range of £1500 to £2000. Point of entry dependent on experience.

Leave on full pay at the rate of 3 months after 15 months' service, with free passages. Marriage allowance £180 per year or free passages for wife each tour. Accommodation, medical attention, laundry and certain other services provided free. Income Tax at low local rates.

Details of training and career to date, in confidence, to BOX No. E7693, "The Engineer."

A

CENTRAL ELECTRICITY GENERATING BOARD

HEADQUARTERS DRAWING OFFICE

Applications are invited for the following appointments at BANKSIDE HOUSE, SUMNER STREET, S.E.1 :

(A) **SECTION LEADER—CIVIL.**
Salary Scale £1105 to £1205 p.a.

(B) **SENIOR DRAUGHTSMEN—CIVIL.**
Salary Scale £980 to £1080 p.a.

(C) **SENIOR DRAUGHTSMEN—CIVIL OR ELECTRICAL.**
Salary Scale £830 to £940 p.a.

(D) **ENGINEERING DRAUGHTSMEN—CIVIL OR MECHANICAL.**
Salary Scale £660 to £780 p.a.

Applicants should be capable of fulfilling the following requirements :

Post (A) Good Civil Engineering experience with several years at Senior level. Ability to administer and control a large Section covering all Grades of Draughtsmen.

(B) Good Civil Engineering experience, competent R.C. designers with ability to supervise under the Section Leader.

(C) Some design experience and capable of supervising Detail draughtsmen and apprentices.

(D) Detailing experience—ability to do simple design an advantage.

Permanent pensionable appointments. Staff Restaurant. Sports and Social Club.

Applications in writing to, or application forms can be obtained from :

The Personnel Officer,
Central Electricity Generating Board,
24-30, Holborn, London, E.C.1.

Envelopes should be marked "Confidential Ref. ENR 425."

E7467 A

IRON AND STEEL WORKS ENGINEERS

METALLURGICAL EQUIPMENT EXPORT COMPANY LTD.,

a consortium of Iron and Steel Works Plant Manufacturers in the export field require the services of the following qualified and experienced Iron and Steel Works Engineers :—

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E2596 A

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E7695 A

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APC

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E7697 A

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E7698 A

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E7680 A

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E7689 A

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November 3	**Miscellaneous stores,** including :	Command Ordnance Sub-Depot, **Devizes.** (Sale at Corn Exchange, Devizes.)	**FARRANT, WIGHTMAN & PINNIGAR** (Dept. L), 2, Newport Street, Swindon, Wilts. (Tel.: 5151-2.)
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November 12-13	**Miscellaneous stores.**	Central Ordnance Depot, **Didcot, Berks.**	**SIMMONS & SONS** (Dept. L), 12, Station Road, Reading, Berks. (Tel.: 54025.)
November 17	**Miscellaneous stores.**	M.O.S. Storage Depot, **Ruddington, Notts.**	**WALKER, WALTON & HANSON** (Dept. L), Byard Lane, Bridlesmith Gate, Nottingham. (Tel.: 54272.)
November 25	**Machine tools and miscellaneous stores.**	Technical Stores Depot, **Old Dalby, Leics.** (Sale at Melton Mowbray.)	**SHOULER & SON** (Dept. L), 1, Norman Street, Melton Mowbray, Leics. (Tel.: 3081.)
December 15	**Miscellaneous stores.**	General Stores Sub-Depot, **Longtown, Near Carlisle.** (Sale at County Hall, Carlisle.)	**HARRISON & HETHERINGTON** (Dept. L), Botchergate, Carlisle. (Tel.: 26292.)

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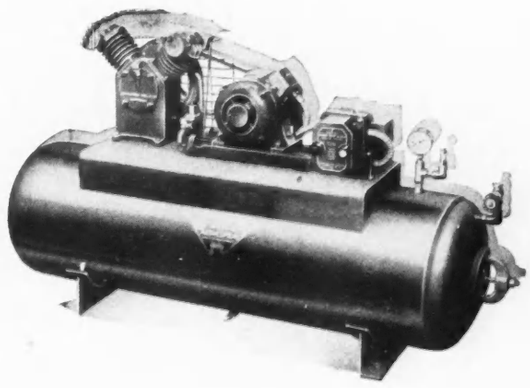

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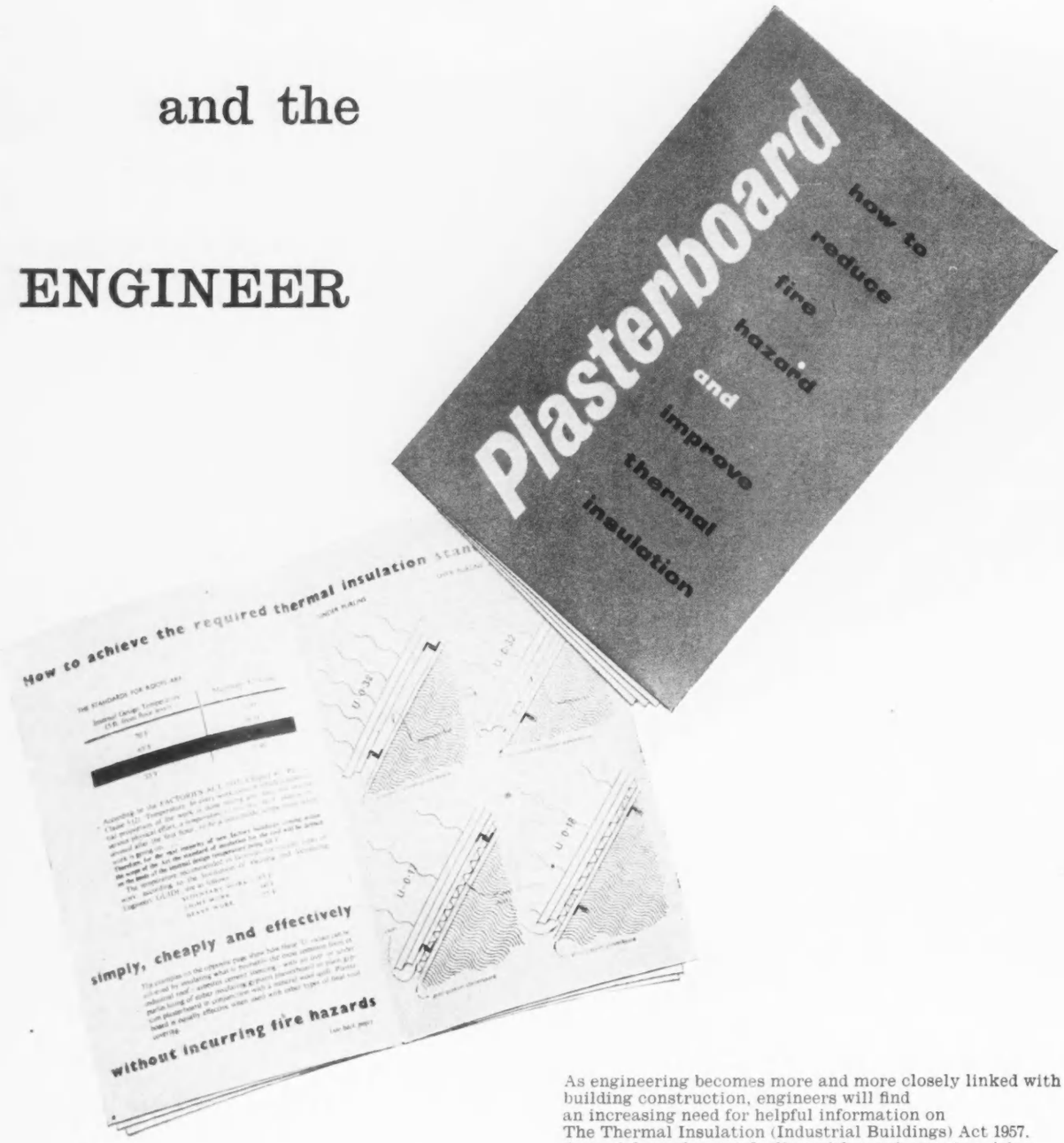
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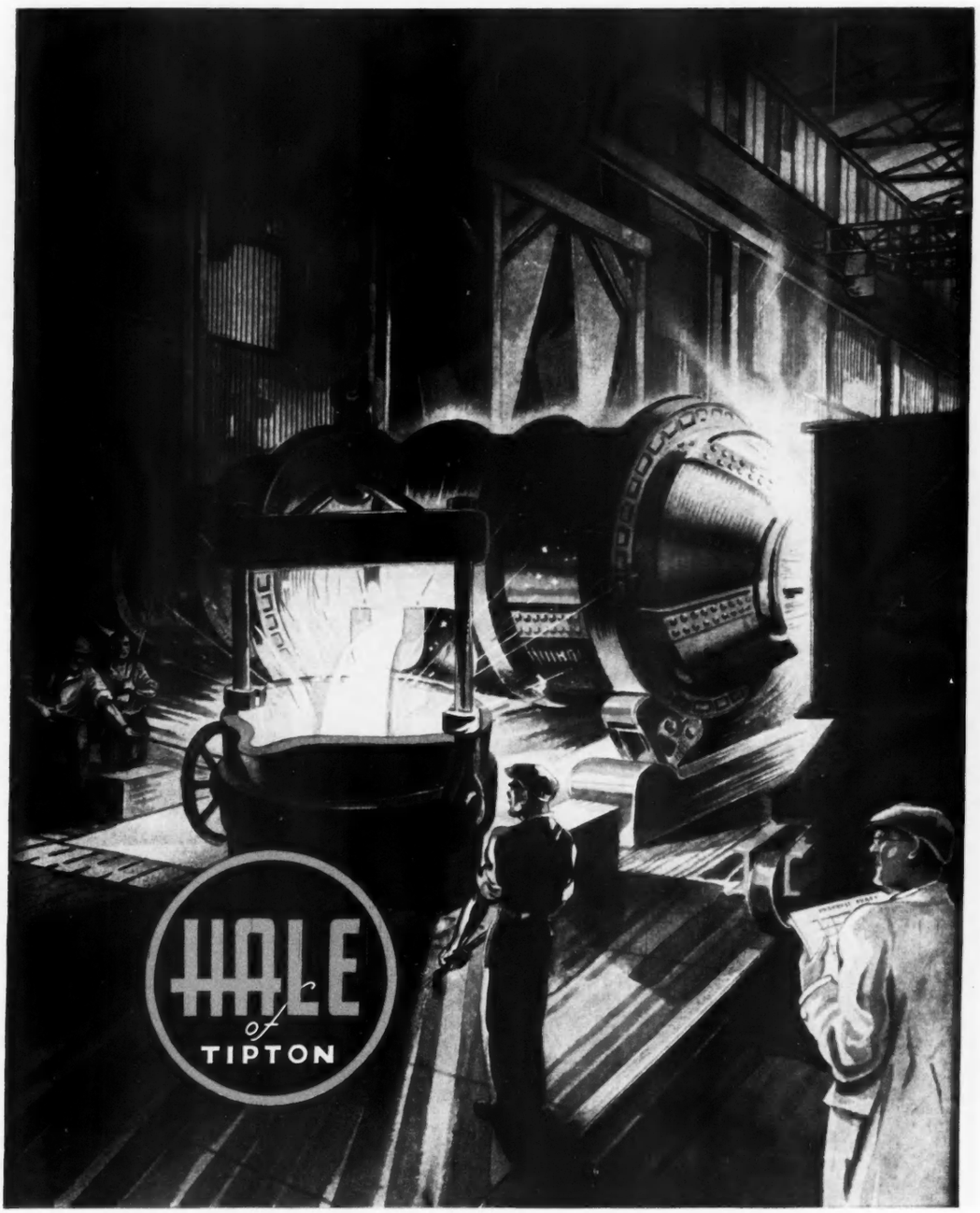

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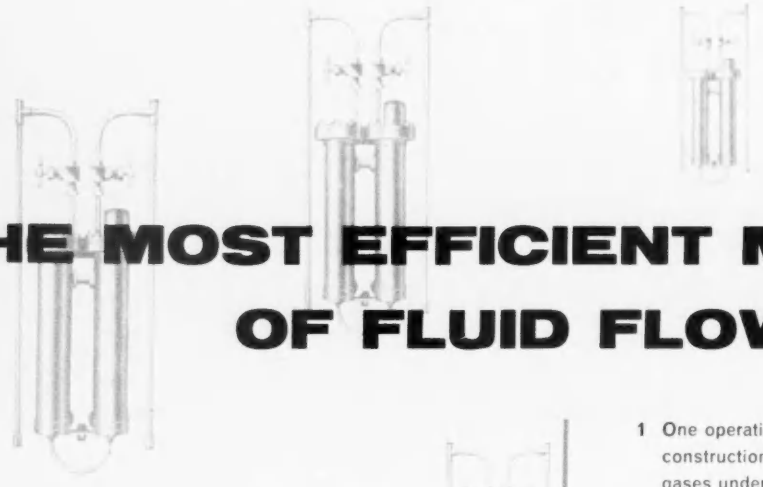

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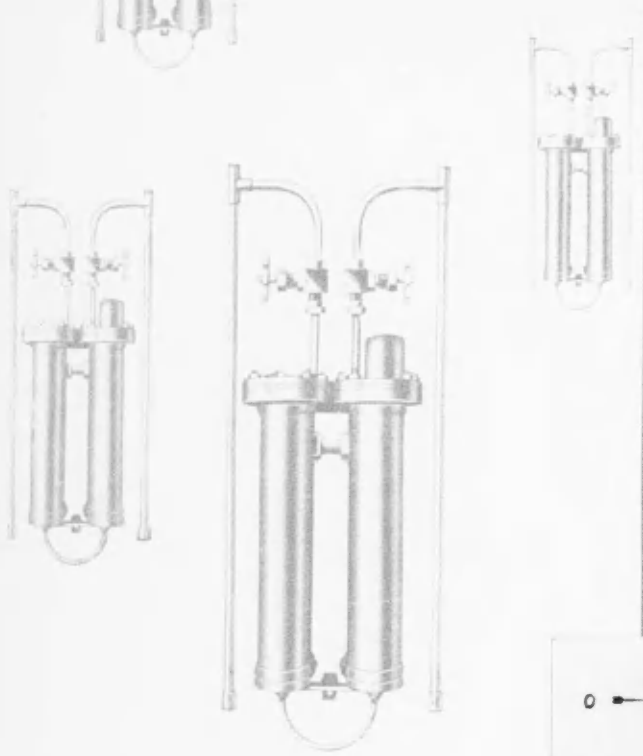

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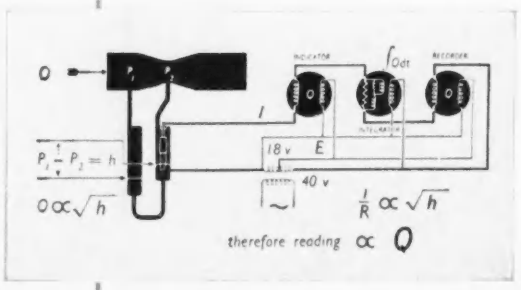

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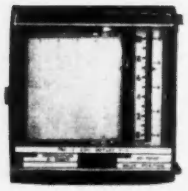

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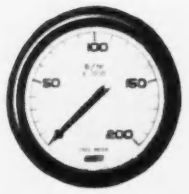

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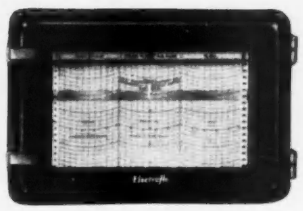

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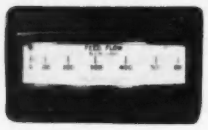

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